A Multilevel Device for Ground-Water Sampling .nd Piezometric Monitoring

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ABSTRACT

A simple inexpensive device for sample collection and for monitoring of ground-water potential at many levels from a single borehole installation has been developed. The device consists of a bundle of polypropylene tubes contained inside a polyvinyl chloride (PVC) pipe that is installed in the aquifer. Each tube protrudes through the wall of the pipe at a different elevation where it serves as a point water sampler and piezometer. The tip of each tube is encased in fine-meshed stainless-steel screening. The device is best suited for use in cohesionless posits and where the piezometric levels are close enough ground surface to enable samples to be obtained by suction methods. It can be conveniently installed using a low-stem auger, driven casing or wash-boring methods. .e usefulness of this multilevel sampling device has been demonstrated in detailed monitoring of a leachate plume from a sanitary landfill.

INTRODUCTION

An important aspect of any ground-water contamination or tracer movement study is obtaining water samples from specific points within the ground-water flow system. Slotted wells tend to provide integrated samples that are mixtures of water contributed by various zones within the screened interval. In many situations, it is desirable to delineate vertical concentration profiles through aquifers rather than collect mixed samples composed of ground water from various horizons. Nests of wells or piezometers with short screens can be used to monitor concentrations at various depths at a site but this approach usually requires numerous boreholes and considerable expense for materials and drilling.

There are various devices or methods for obtaining vertical concentration profiles in ground-water flow systems. The procedure described by Yare (1975) for ground-water sampling consists of drilling to the sampling horizon, lowering a well screen on the drill string in place of the bit, gravel packing the screen, pumping until discharge clears of drilling fluid, pumping and collecting the sample, removing the screen and drilling to the next horizon. This method is expensive and very time-consuming, and as indicated by Yare has the disadvantage of not allowing for sampling at future times because there is no permanent borehole installation.

In this paper an alternative approach which has particular suitability for use in cohesionless deposits with shallow water levels and primarily horizontal flow conditions is described. It consists of a device that can be easily installed in a single borehole. It can be used for rapid collection of ground-water samples at numerous levels and also for measurement of hydraulic head at these levels. It has some similarities with the ground-water profile sampler described by Hansen and Harris (1974) but their sampler requires the use of well points, probably has greater susceptibility to short circuiting between sampling levels, and is cumbersome to construct for long samplers with many sampling points. The ground-water sampler described by Merritt and Parsons (1960) which utilizes extraction thimbles located at different depths is also similar but it requires a larger casing for installation and much greater sampling times.

Networks of the samplers described in this paper have been used successfully in three sh[illegible] fine-to-medium-grained sand aquifers and in shallow gravel aquifer. Aquifers [illegible]

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: multilevel sampling device provides . cient and economical means of monitoring se aquifers, even in situations where contaminant ;ra patterns are complex as a result of aquifer ei neity. For monitoring of waste management ilities on or near permeable deposits, these ices can serve as an alternative to, or a supple- nt to, the use of observation wells or piezometers more conventional design.

The purpose of this paper is to describe in ail the design, construction and methods of allation of the device. Data are presented to strate the type of results that can be obtained en the device is used in sand and gravel aquifers. e more extensive results and their interpretation m field dispersion tests and monitoring of a chate plume is described elsewhere.

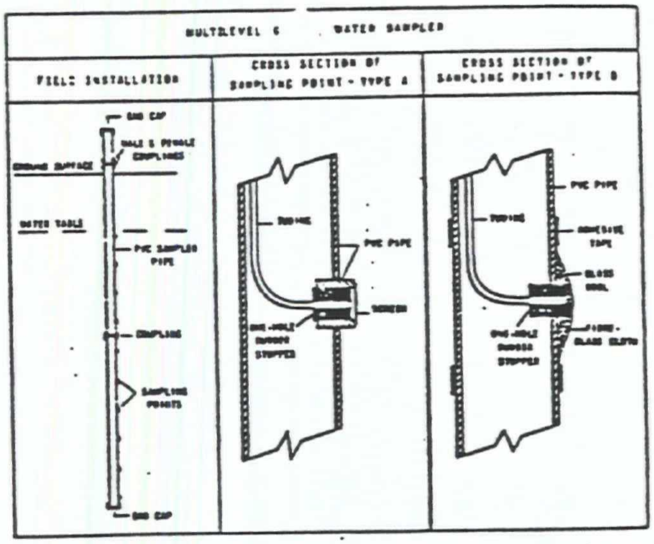


Fig. 1. Schematic diagram of the multilevel sampling device.

CONSTRUCTION AND INSTALLATION OF THE MULTILEVEL SAMPLING DEVICE

A schematic of the completed multilevel npling device is shown in Figure 1. This Figure istrates two designs that have been used for ling points. The device can be easily nstructed in the field providing electrical power ava ble or alternatively the holes in the PVC be drilled at predetermined spacings before e pipe is transported to the field site. An vantage to preparing the devic on site is that the sampling points can be located on the basis of stratigraphic information obtained from the bore-hole into which the device is to be placed.

A detailed description of the construction of a multilevel device with type A sampling points is as follows. The materials necessary are listed in Table 1. The sampler pipe which is 4.3 cm O.D. (1¼-inch nominal) PVC pipe is cut and glued to the required length. Holes of 2.1 cm diameter are drilled with a hole saw in the sampler pipe at the sampling point

Table 1. Materials for Multilevel Sampling Device

Material	*Dimensions*
e-hole rubber stopper	No. 00; use larger half
ainless steel screen	100 mesh X 1.9 cm diameter
lyvinyl chloride (PVC) pipe	(a) 4.3 cm outside diameter (O.D.) 3.4 cm inside diameter (I.D.) Nominal size—1¼ inch, schedule 40 Length—as desired (b) 2.1 cm O.D. 1.3 cm I.D. Nominal size—½ inch schedule 80 1.6 cm length
reamline PVC couplings	Solvent type To connect 4.3 cm O.D. PVC pipe
nd caps	To fit 4.3 cm O.D. PVC pipe
ale threaded to streamline PVC couplings	To fit 4.3 cm O.D. PVC pipe
e hreaded to streamline PVC couplings	To fit 4.3 cm O.D. PVC pipe
V nt cement	
ly. pylene tubing	0.32 cm ($^1/_8$ inch) O.D. 0.04 cm (0.016 inch) wall thickness
ubing template	Polyethylene 3.5 cm diamete 0.3 cm thickness Holes drilled for sampling tubes

positions. The polypropylene tubing is fed through these holes and extended 0.5 metre beyond the coupling corresponding to ground surface. A No. 00 -hole stopper (half-length) is fitted on the polypropylene tubing and glued into the sampling point. The sampling point consists of a 1.6-cm length of 2.1-cm O.D. (½-inch nominal) PVC pipe with a circular piece of 100-mesh stainless steel screen attached to one end by melting the PVC. The sampling point assembly is glued into its corresponding hole in the sampler pipe. Identification of the position of each sampling point is established by its position in a template at the ground surface coupling. The sampling tubes are protected above ground surface by an extension of the sampler pipe which can be removed during sampling and monitoring. Cost of materials for a multilevel sampler of total length 12 metres with 20 sampling points is approximately $60.00. Three man-hours are required for construction.

Construction of a multilevel sampler having sampling points of type B (Figure 1) is similar. In this case, the rubber stopper is fitted directly into 0.95-cm hole in the sampler pipe. This sampling point is covered with glass wool and wrapped with fibreglass cloth. Both types of sampling points have been used successfully.

All sizes of materials mentioned above are for descriptive purposes. They could be modified to suit the particular application. For example, if more than 30 sampling tubes are required, it would be advantageous to use a larger diameter container pipe. The diameter or pipe used in our investigations was convenient for installation down the 9-cm diameter bore of the hollow stem augers or 7.5-cm inside diameter of wash-boring casing that were used for drilling. If there is concern that leaching of the PVC pipe may lead to unreliable chemical data from water samples, as may be the case in studies of some types of dissolved organic compounds in ground water, use of other types of plastic or metal pipe would be appropriate.

The multilevel sampling device can be installed through the bore of hollow stem augers, through casing driven by a cable-tool, percussion drill or by wash-boring. The auger or casing is driven to the desired depth, the multilevel sampling device is installed down the auger bore or casing, and the auger or casing is withdrawn. In cohesionless deposits the pipe becomes secure in the ground as the deposits collapse in around it. We expect that the multilevel sampling device could also be used in cohesive deposits such as silt or glacial till. In these materials it would be necessary to install clay or gr seals between the various sampling tips in order to isolate the sampling points at each level in the borehole.

WATER SAMPLING

The multilevel monitors are suitable for use in aquifer zones with water levels that are sufficiently shallow to allow sampling by vacuum pumping. Thus, the sampling points can be located many tens of metres below ground surface providing the water levels are shallow.

Before taking a sample for analysis, a volume equivalent to or greater than that initially in the sampling tube is removed and discarded. This flushing procedure can be accomplished rapidly by pumping groups of the tubes simultaneously by connection to a large vacuum flask and applying a vacuum. After flushing, a sample is taken from each tube individually. Typical flow rates for the tubing used in the sampler described are 150 mℓ/minute through 12 metres of tubing and in a fine to medium sand environment. Initially, flow rates may be low as a result of clogging of the sampling points by finer material. However, except in very fine-grained deposits, a minor amount of backflushing through the tubing will usually correct this problem. Once a sampling point has been cleaned by backflushing, it is rarely necessary to repeat the backflushing process.

Because the inside diameter of the tubing is quite small, water drawn by vacuum moves quickly from the formation to ground surface. The water can be pumped directly into an air-exclusion cell for measurement of pH and Eh. Quick passage from the aquifer to the cell should minimize the degassing of the water. For the flow rate mentioned previously the rate of travel through the tubing is about 36 cm/sec. If too much vacuum is applied quickly to the sampling tube, the water column will separate and some degassing may occur. There is no difficulty insuring that stagnant water in the tubing is removed because the entire water column flows as pumping occurs. In the sampling of wells or piezometers, removal of all stagnant water prior to sampling can be a problem. When a sampling tube lowered into a conventional piezometer or well is pumped, the water can be derived from various layers in the screened zone and from older water in the water column. Pumping of an equivalent water column volume from the piezometer or well does not establish that further pumping produces sample water entirely from the formation. Simulation studies by Narasimhan *et al.* (1976) have established that s or days of production of water mixed the two sources can occur. Also wh ıction is entirely from the screened formation, ater can be a mixture of waters of different y n individual layers within the production

EASUREMENT OF HYDRAULIC HEAD

It is possible to measure the hydraulic head ch sampling tube using the apparatus shown in e 2. The lip of the coupling on the top of the ler pipe is chosen as the reference elevation. ıead measuring device consists of a transparent glass tube with a solid rubber stopper in the and a two-hole rubber stopper in the top. The glass tube contains a reservoir of mercury and le mounted to a piece of tubing of the type in the multilevel sampling device. The top of the reservoir of mercury is made level the reference elevation. To obtain a hydraulic l measurement, the multilevel sampling device is connected to the above device as shown in ıre 2. A vacuum is then applied to the plexiglass . Once the tubing is completely filled with vacuum is released. Mercury will be vn the tubing and reach a static level. The h water, d, below the reference elevation ed from the following expression (see ıre 2):

$$d = 13.6\, h_m - h_w.$$

s level defines the piezometric water level responding to the position of the sampling nt in the subsurface.

In field situations where the vertical gradients small, it is best to use the device shown in ure 2 to obtain the piezometric level for one of tubes. This tube is used as a reference tube l all other piezometric levels obtained are ative to it. A vacuum is applied through a nifold to the reference tube and several other es simultaneously, raising the water levels in tubes to above ground level. The difference in ter level between the reference tube and the ıer tubes is used to determine the piezometric el in each individual tube. This and the above hnique for determining piezometric levels can ly be used where the piezometric levels are at close to ground surface because of the nd for the water column in the tubing separate as depth to water below ground rface increases. For example, it has been used cessfully where the depth to water table was n but unsuccessfully where it was 5 m.

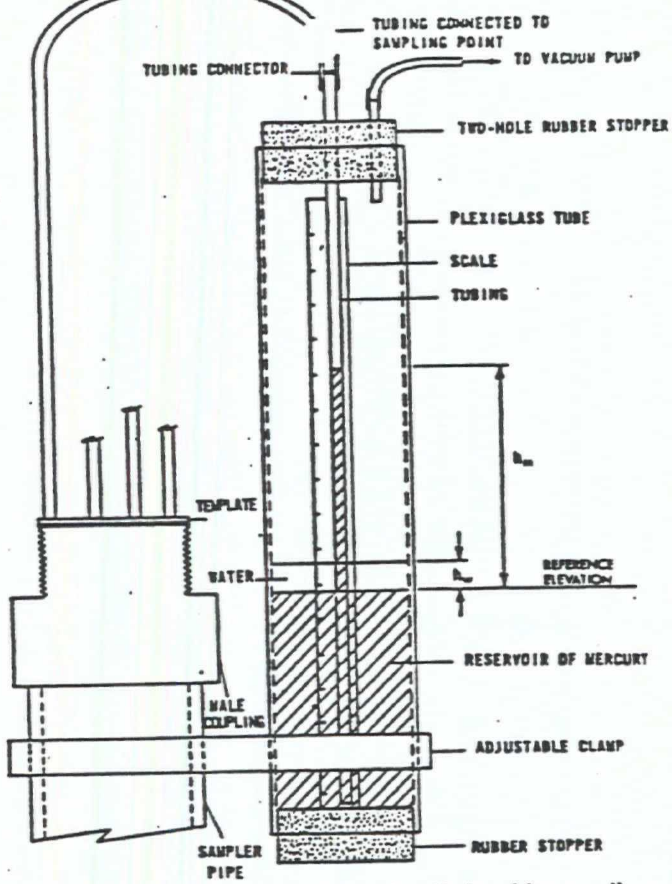


Fig. 2. Apparatus for measuring hydraulic head in sampling tubes.

Using mercury in the hydraulic head measuring device means that any inaccuracy in reading the mercury levels is greatly magnified (that is, by 13.6) when converted to head of water. For certain situations, it might be appropriate to choose an immiscible fluid other than mercury for head measurement in order to minimize this inaccuracy.

DISCUSSION

The multilevel sampling devices described in this paper were developed initially for use in field dispersion tests with artificial tracers. The results of these applications are described by Grisak *et al.* (1977) and Pickens *et al.* (1977). Results are presented here to demonstrate the capability of the device in monitoring zones of subsurface contamination. The device was used to obtain detailed information on the vertical distribution of nitrate in a shallow sandy aquifer that is contaminated as a result of heavy fertilizer use. Also, a network of the devices was used to delineate the position of the contaminant plume migrating from a sanitary landfill.

Concentration profiles from sa ,es taken from a piezometer nest and from an adjacent pair of multilevel sampling devices in the nitrate-co ninated aquifer are shown in Figure 3. C. ntration of NO_3-N in ppm is plotted versus depth below ground surface. The solid vertical bars indicate the screened interval of the individual piezometers and the x's indicate the depth of the sampling points in the multilevel sampling devices. The profiles obtained from these two types of monitoring devices are in general similar, with minor variations probably due to the fact that the piezometer screens receive water from a vertical interval that is large in comparison to the zone sampled by each of the intakes in the multilevel sampling device. The device was found to be well suited for detection of the NO_3-N profile in the aquifer. One of the major advantages of the multilevel sampling device is that detailed concentration profiles can be obtained at a much lower cost than with piezometer nests.

The most recent and extensive use of the multilevel monitoring device has taken place at a s ry landfill at the Canadian Forces Base at B en, Ontario. The existence of a large zone of sub urface contamination had been established

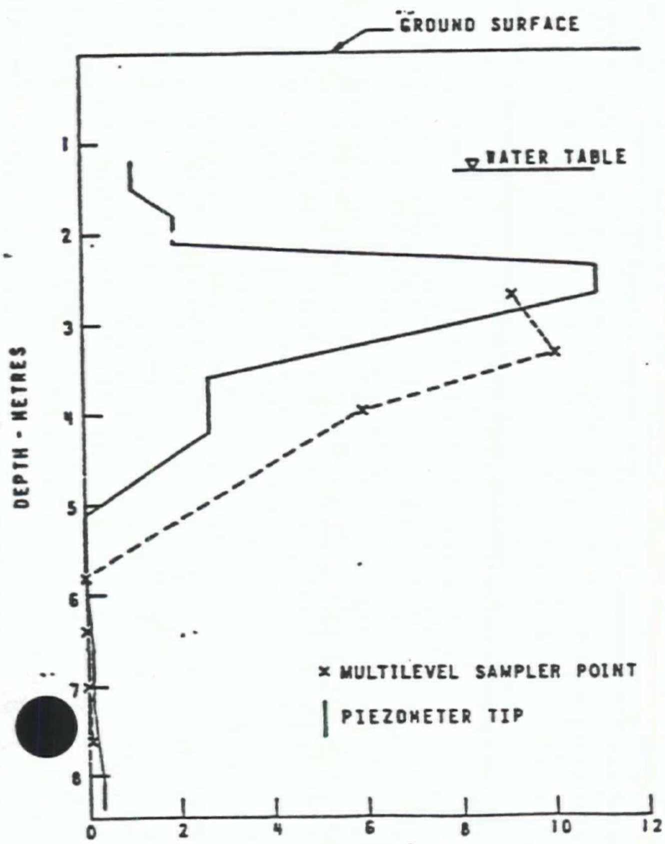


Fig. 3. Comparison of NO_3-N profile from samples obtained by piezometers and by multilevel samplers.

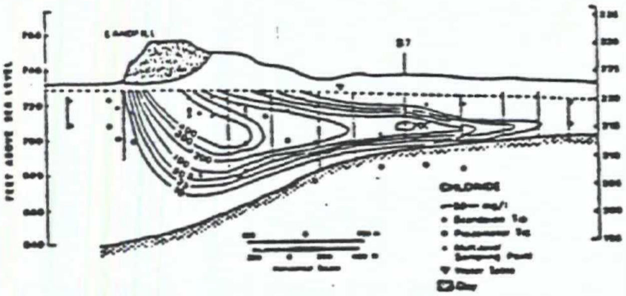


Fig. 4. Chloride concentration distribution on cross section through sanitary landfill obtained from network of multilevel samplers.

from previous investigations (Gartner-Lee Associates, 1977) using piezometers and wells. A network of the devices was installed in order to determine in detail the distribution of leachate-contaminated water beneath the landfill and beyond the landfill. The plume position and extent have been defined on the basis of chloride and specific conductance measurements. The chloride concentration distribution obtained using the multilevel samplers on a cross section through the sanitary landfill is shown in Figure 4. This cross section is chosen along the main ground-water flow path at the site. The chloride concentration and specific conductance profiles for the multilevel sampling device located at the position denoted S7 on Figure 4 is illustrated in Figure 5. The stratigraphy is shown on the left and the depths of the sampling points are indicated by the x's. These profiles are indicative of the nature of the chloride and specific conductance data that has been obtained from the monitoring network. The network of multilevel devices is currently being used for monitoring a wide variety of chemical constituents. They are providing an effective and relatively inexpensive means of defining the spatial distribution and temporal variations of the contaminated zone.

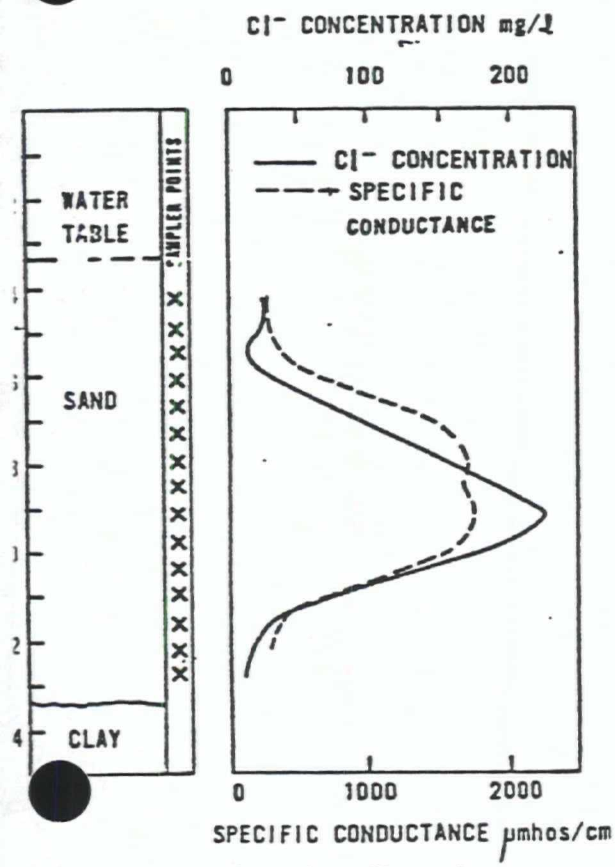
It is envisioned that the design of a monitoring network for a waste-management site would include a system of wells, piezometers and multilevel samplers. The wells and piezometers could be used to establish the physical ground-water flow regime and the multilevel samplers could be used to identify and monitor the extent of the contaminated zone.

CONCLUSIONS

A ground-water monitor has been devised which is suitable in cohesionless deposits for detailed ground-water sampling and piezometr measurements. The advantages of the monitor

device is installed permanently
monitoring at future times; (he
allows ground-water samples and
ılic-head measurements to be obtained from
depths with a single borehole installation,
reducing drilling costs; (3) the device
.ive; (4) it can be easily constructed in
ld; (5) the samples obtained are from a
point rather than from a larger mixed
s in slotted wells; (6) the volume of
nt water that must be removed from the
ng tube before taking a sample for
is is small, thus reducing sampling time and
bance of the flow regime around the
ing point; and (7) the sample is collected
ly, thus minimizing its deterioration due
gassing or oxidation.

Networks of these devices can be used as an
nt means of monitoring zones of contamina-
ı shallow granular aquifers where water levels
fficiently shallow to permit sampling by
m methods and where flow directions are
rily horizontal minimizing any vertical
nent of water through the zone disturbed
drilling.



Chloride concentration and specific conductance
s obtained from one of the multilevel samplers
d within the leachate plume.

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