ACADEMIC TRAINING FOR GROUNDWATER QUALITY SPECIALISTS

by

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The objective of this article is to propose a much needed academic program to educate hydrogeologists for specialization in groundwater quality. Groundwater geology or hydrology is a relatively new discipline compared to most other fields of endeavor, and specialties are rapidly developing. Some of these specialties are geophysics, temperature studies, modeling, aquifer analysis and pump testing, and water quality. Water quality has recently been elevated to a much higher importance than previously. This importance is related to increased groundwater development, increased waste disposal to groundwater, and to an increased awareness of groundwater quality and pollution (Pettyjohn, 1972).

Evans and Harshbarger (1969) discussed curriculum development in hydrology. These authors mentioned the emphasis that some university programs had given to water pollution and waste disposal in the 1960's. They also pointed out that this area of water resources education is closely allied with sanitary engineering and agricultural programs. These authors presented data on the estimated expenditures for water resources research during 1966 and 1971. Such data provide a basis for indicating the future demand for hydrologists. Total research activity was expected to double during these five years. Of nine water research categories, the greatest increase was indicated for one entitled "water quality management and protection", where expenditures were projected to quadruple between 1966 and 1971. I have no estimates for the recent five-year period nor the future, but the changes should be even more profound.

With future increases in population and water use, there will be increased groundwater development. This will occur both in the U. S. and in many other parts of the world. Salinity is a common problem in groundwater of arid lands. Undoubtedly, great consideration will be given to the use of saline groundwater resources on a world-wide basis (Summers and Schwab, 1970). Each aquifer generally has a unique set of water quality problems, due either to natural or man-made factors. Water quality studies are an essential part of groundwater exploration and development programs, and serve two purposes. First, they indicate the quality of water which can be withdrawn from the aquifer for a specified use. Secondly, groundwater quality data can be compared with interpretations of the hydrogeologic system based on physical or hydraulic data. Temperature and chemical quality data can be interpreted in conjunction with hydrogeologic data to confirm or negate concepts of the groundwater system.

Nationally, the Safe Drinking Water Act (Public Law 93-523) of 1974 has already resulted in increased awareness of the importance of groundwater for domestic supplies. With the National Interim Primary Drinking Water Regulations to be applicable to most domestic water supply systems (Environmental Protection Agency, 1975), increased use of groundwater will occur in some areas, particularly in the eastern U.S. This is due to the difficulty in treating some surface waters to the extent necessary to meet the new standards. Increased irrigation and energy development in the western U. S. also depend on additional groundwater development.

Lastly, the widespread occurrence of groundwater pollution is beginning to be recognized. In my opinion, our studies of groundwater pollution are only in the elementary stages, particularly for diffuse sources. With the trend toward land disposal of many wastes (Thomas, 1973) due to stricter regulations on waste disposal to the air, surface water, and the ocean, much greater waste loads will be applied to the nation's aquifers. This trend is occurring despite the long residence time of pollutants in aquifers and the many unknowns involved. Due to its "out of sight - out of mind" nature, groundwater pollution is often extremely difficult to understand for polluters, regulatory agencies, decision makers, and the general public. Ferris (1972) stated, "There has not been general recognition of the cumulative effect upon the hydrologic system of seepage from sewage lagoons, sanitary landfills, septic tanks, and spray disposal of sewage effluent, and incidental recharge in influent seepage from countless miles of sewerage systems." The three National Groundwater Quality Symposiums held between 1971 and 1976 help focus attention on the problem.

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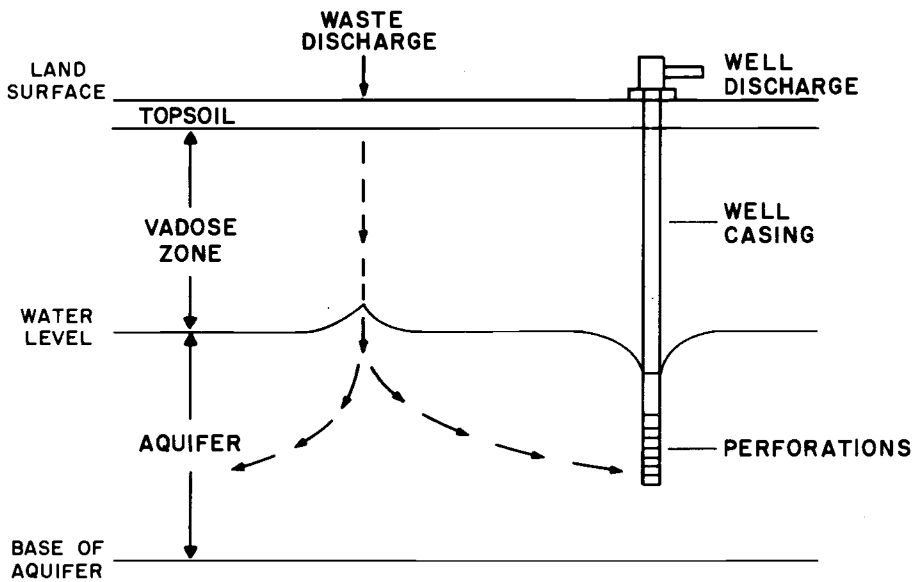
Education is an important factor in the long-term solution to many groundwater pollution problems. This article mainly concerns the academic training required for hydrogeologists who will conduct groundwater pollution ivestigations in the future. However, much of this training is dependent upon, and applicable to, considerations of natural groundwater quality.

CURRENT APPROACHES TO GROUNDWATER POLLUTION EVALUATIONS

It is somewhat ironic that many people currently working in the water pollution control field are in fact not well trained in groundwater. In part this has been due to a pre-occupation with surface water. One large group of people currently works with waste treatment and disposal, and primary consideration is given to land-surface phenomena. Understanding of soils and hydrogeology by this group in the past has often been inadequate. Analysis of the impact of waste treatment and disposal on groundwater quality seems to have been relegated to a secondary position at best. The tendency has been to treat municipal wastes with little regard to whether disposal is to surface water or groundwater, despite the differences in pollutant attenuation characteristics of these two systems. Secondly, land disposal is being stressed without adequate knowledge of the groundwater system in many areas. Many of the regulatory agencies responsible for protection of groundwater quality are staffed with, and administered by, personnel belonging to the same group.

Another broad group of people working with groundwater pollution can be classified as soils scientists. This group is presently coming to the forefront in land disposal considerations, as well they should. Their field has long been neglected or overlooked by others. A very important extension of the work of soils scientists has been to extend research beyond the topsoil into the vadose zone. Despite the importance of water quality changes in the topsoil, they can be overemphasized. Two unfortunate tendencies are presently occurring: 1) the erroneous assumption that the entire soil-aquifer system is comprised of materials comparable to topsoil, and 2) ignorance of what happens after pollutants reach the water table. Many soils investigations stop once the pollutant moves beyond the topsoil; however, some investigators do follow pollutant movement through the vadose zone to the water table. To date, I believe that hydrogeologists have often taken a back seat in the field of groundwater pollution to the first two groups. Knowledge of land surface phenomena and subsequent water quality changes in the topsoil and vadose zone during percolation is essential; however, for proper interpretation, the entire system must be analyzed. The following figure illustrates the framework for monitoring groundwater pollution.



SCHEMATIC DIAGRAM ILLUSTRATING FRAMEWORK FOR MONITORING GROUNDWATER POLLUTION

Groundwater is ordinarily withdrawn by wells for use. Therefore, the portion of the system between the water table and the well discharge must also be analyzed. Most aquifers do not lend themselves to generalities in terms of groundwater pollution. Geologists and hydrologists working directly with groundwater have a unique opportunity to contribute to groundwater pollution investigations. If information on pollution sources and processes occurring in the soil and vadose zone is unknown or poorly known, then interpretations of the results of well sampling are marginal at best. Pollutant travel and attenuation, from the pollution source to the well discharge, can be assessed. Consideration of the entire soil-aquifer system can lead to a unique and accurate understanding of groundwater pollution.

THE SYSTEMS APPROACH

Components of the groundwater pollution system include:

1) Sources of Pollution and Pollutants Present
2) Method of Waste Disposal
3) Infiltration Potential of Wastes from the Land Surface
4) Downward Movement of Percolate in the Vadose Zone
5) Pollutant Attenuation in the Topsoil and Vadose Zone
6) Movement of Recharged Water in the Aquifer
7) Pollutant Attenuation in the Aquifer
8) Well Construction, Hydraulics, and Pumpage

These components determine the training necessary for the groundwater quality specialist. The training must include analysis of land surface phenomena, such as pollution sources. Strong emphasis should be placed on the physical, chemical, biologic, and hydrologic characteristics of soils. Water and pollutant movement under unsaturated flow conditions must be assessed. Historically, the vadose zone has often been approached by the "black box" method, but this approach will no longer suffice in groundwater quality investigations. The effects of aquifer characteristics and well pumpage on pollutant attenuation must be evaluated. Soils chemistry, geochemistry, and physical chemistry can be used together in a powerful approach which can also be used in groundwater quality investigations not specifically concerned with pollution. The foregoing components can be addressed by an academic training program as discussed in the following sections.

MASTERS PROGRAM

A successful Masters degree program would establish a strong academic background in groundwater hydrology. A thorough understanding of groundwater quality is dependent upon a thorough understanding of the physical aspects of groundwater systems. Courses on aquifer mechanics and groundwater development are in existence in a number of universities. Groundwater courses should be based on a strong geologic orientation. Related topics of value include meteorology, surface water hydrology, watershed management, soils physics, and geomorphology. Introductory courses in physical chemistry, geochemistry, and soils chemistry are advisable, but there is no necessity to include advanced water quality courses. A newly developed course strictly on groundwater quality would be beneficial. After completion of the Masters degree (including thesis), several years of work experience in groundwater hydrology would be extremely useful before advanced graduate work was undertaken.

DOCTORAL PROGRAM

With a solid background in groundwater hydrology established and the elementary courses related to groundwater quality completed during the Masters program, the doctoral program would focus directly on sources of pollution and groundwater quality. Topics related to pollution sources include irrigation, fertilizer management, mining, chemical engineering, and sanitary engineering. Advanced classes would be taken in soils chemistry, biochemistry, and geochemistry. Most of these classes are in existence at many universities, however, they could be modified to be more suitable for the training of groundwater quality specialists.

For example, agricultural activities are of primary concern in the San Joaquin Valley, California. Obviously, irrigation practices, including fertilizer and pesticide applications, may have a significant impact on groundwater quality. Wastes from dairies and feedlots are also important. Courses on irrigation, soils management and animal science are usually taught in the agricultural departments of most universities. Relevant textbooks on these topics are available (Willrich and Smith, 1970, American Society of Agricultural Engineers, 1971, and Soils Science Society of America, 1974). Special types of waste are generated by agricultural processing facilities. Wineries, canneries, and meat-packing, milk processing, olive processing, and citrus packing plants produce unique types of wastes which may affect groundwater quality. The Journal Water Pollution Control Federation contains invaluable information on waste composition, treatment, and disposal. Some of these topics are covered in classes at some universities on enology, biochemistry, animal science, and possibly chemical engineering. Oilfield wastes are of significant importance in the western and southern parts of the valley. Courses in petroleum geology and related topics could be useful. Lastly, disposal of municipal liquid and solid wastes are important near the larger urban centers (Sopper and Kardos, 1973, and Sanks and Asuno, 1976). Information on these wastes would normally be covered in sanitary engineering classes.

It would appear that mining and milling, and leaching of ore deposits are of primary concern in southern Arizona. Courses in mining geology, geochemistry of ore deposits, ore benefication, metallurgy, and engineering geology could be applicable. Several excellent textbooks have recently been published related to mining and milling wastes (Hadley and Snow, 1974, and Williams, 1975). Municipal wastes are of concern near the urban centers and agricultural practices are important in irrigated areas.

Several classes are necessary which are presently rare or non-existent in most universities. The low temperature, low pressure geochemistry of dilute solutions is of great importance. The hydraulics of water flow in the vadose zone needs to be given detailed consideration. Water quality changes in the topsoil and vadose zone are commonly described in Journal Environmental Quality and Soil Science Society of America Journal. An advanced class in groundwater quality and another in the mechanics of groundwater pollution would be appropriate. A number of examples of monitoring groundwater pollution have been published in Ground Water. Special classes on analytical methods for the physical, chemical, and radiological examination of water should be included. Sampling methods and frequency of sample collection should be discussed in detail.

SUMMARY

The training of groundwater quality specialists will be of extreme importance in the future. This is related both to increased groundwater development and waste disposal. Adequately trained hydrogeologists can work in conjunction with engineers, soils scientists, and others to understand groundwater pollution mechanisms. The current trend toward widespread land disposal of many pollutants in the U. S. poses a serious threat to the integrity of groundwater quality. Education of hydrogeologists with an emphasis on water quality will have a beneficial impact.

I have proposed a partial solution to some of our future groundwater quality problems. Besides hydrogeologists, the public in general should be educated, as well as students in grammer school, high school, and college. I think this is a meaningful and practical approach on a long-term basis. However, there is another aspect involved. In my limited experience, pollution of groundwater often results from 1) ignorance, or 2) willful neglect. Education may be an answer to the first, but it is not to the second. Groundwater pollution cannot be effectively mitigated without consideration of both of these basic causes. Consideration of the second lies within the hearts of men and is beyond the scope of this paper.

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