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The Use of Ionic Tracers in Determining the Subsurface Flow of Mine Drainage. A Case Study.

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INTRODUCTION

The use of ionic tracers in determining subsurface flow of ground water, especially the subsurface flow of mine drainage, has been very limited. The use of ionic tracers as a tool in ground water investigations is in its infancy. This tool may prove to be very useful. However, at the present time, its use is limited. The proper use of this tool must be developed, but it must be developed with caution. This entails time, money and experimentation; and it may not always prove to be the best method available in evaluating every problem. Therefore, the purpose of this paper is to present some insight into the potential use of ionic tracers for monitoring ground water movement and an example of their use in a particular case study area.

The hydrogeologic framework and the hydrologic characteristics of the study area must be determined. Geologic field work, the gathering of all available historical or published information, and the evaluation of this data gives a basis understanding of the hydrogeology. Supplementing the previous method of investigation with a program of well drilling, well logging, water level recording, ground water quality monitoring, and pumping tests produces a very accurate definitive understanding of the hydrogeology. However, sometimes it is not enough to do all the previous described investigation. Therefore, the use of tracers may be required to develop a more thorough understanding of the hydrogeology.

The complexity of the problem dictates the degree of understanding required to fully evaluate the hydrogeologic framework and the hydrologic characteristics. The complexity of the problem and the hydrogeology determines what tracers should be used. The different tracers have different limitations. There are two basic types of tracers: those naturally existing, or those introduced into the system.

Naturally occurring tracers are those present in the hydrogeologic system. They exist naturally as ionic constituents of the ground water. Natural tracers have been used in geochemical prospecting for ore bodies.

In hydrogeologic studies natural tracers can prove to be a dilemma since they are already present in the ground water. But the resolution of the problem under study may affect the concentration of the tracer by increasing to the concentration, or by chemical reactions which may decrease or increase the concentration.

The types of tracers which may be introduced into the hydrogeologic system may be radioactive tracers, dyes, or ionic tracers. Radioactive tracers produce an evil stigma of long-term pollution to the general public when public and private water supplies are involved. One of the time-consuming problems with radioactive tracers is that the distributing agents or companies must be licensed by the Atomic Energy Commission and they must also obtain subsequent approvals from the responsible state regulatory agencies. In Pennsylvania this would be the Department of

THE CASE STUDY

The location of the case study area is in south central Clarion County. The surface and near-surface rock units range in age from lower Pottsville sandstone formations up through the sandstone-shale formations of the middle Allegheny Group. Specifically, the key marker units in the described section are the lower and upper sandstone members of the Conoquennessing Formation and the Homewood Sandstone of the Pottsville Group, and the Brookville Coal, Clarion Coal, Vanport Limestone, and the Lower and Middle Kittanning Coals of the Allegheny Group.

Physiographically, the surface is moderately dissected; relief is 300 - 400 feet. Surface water drainage is northward to the westward flowing Clarion River which then flows southward in the Allegheny River.

Gentle low amplitude structures in the region reflect a general regional northeast - southwest strike; however, the study area was located along a very shallow basin-like depression. Therefore, dips of the surface rocks are gentle, being only a few degrees; however, the bedrock has highly fractured zones developed.

Three public water supply wells had been drilled by a municipality at almost stream drainage level. The basis of the water well locations were determined by fracture trace analysis of aerial photo interpretation. Two wells were located on abandoned spoil banks created by first generation of strip mining conducted in the late 1940's. A third well was located a short distance from the spoil bank. Two of the wells penetrated the Pottsville Group section; water yields proved adequate but water quality proved marginal.

Recent renewal of stripping operations posed the question of the potential deleterious effects upon the already marginal quality of the available water supply.

The Commonwealth's Bureau of Water Quality Management (Ground Water Section) in conjunction with the coal operators (and their consultants) and the municipality established a test program to determine the hydrological performance of the zone of saturation within the described geologic section. Performance data of the test program then was to permit a comprehensive evaluation of the current and subsequent effects of stripping mining operations on the water supply wells. Other factors considered in the evaluation were the effects of deep mines which were abandoned 20 - 30 years ago. The terminal points of the water-filled mine entries were located up-dip and within 1400 feet of the coal outcrop zones and water wells.

The scope of investigation of the test program was quite comprehensive and briefly summarized below:

1. A core test hole through Lower Kittanning coal which was deepened to provide complete lithologic description through sandstone member units in the Pottsville Group.

2. A mechanical logging program (gamma-ray and other nuclear logs) of the core test hole and one of the water supply wells was conducted to supplement lithologic description and geologic correlation of all key member units, provide quantitative analysis of primary reservoir characteristics of sandstone aquifer units, and precise depth control to permit the isolation of selected vertical zones in the bore hole for straddle packer pump tests.

3. A straddle packer testing tool with air inflated packing devices, submersible pump attachment and monitoring tubes for drawdown measurement was used in one of the water supply wells to selectively test six zones in the bore hole for

Environmental Resources. Other limiting factors to be considered are their cost and the cost of effective measurement devices.

Dyes have been used in the past to examine problems in very small areas. There are three basic dyes used: rhodamine, urinine and flourecene. Rhodamine is no longer used because it is carcinogenic. And carcinogenic compounds are thought to produce cancer. Urinine is good in certain environments over relatively short distances. In acid environments urinine dye breaks down and is not useful. The flourecene dye is used in checking water movement in free flowing systems. In the hydrogeologic environment the flourecene dye is of little use because it adheres to clay minerals present in the environment.

The third group of tracers are manufactured chemical compounds used as ionic tracers. The use of ionic tracers also present significant problems, but may ultimately prove to be the most reliable when utilized in ground water studies. The irresponsible introduction of ionic tracers to the ground water system can cause pollution. The use of different tracers even at low concentrations may produce long-term harmful results to the hydrogeologic environment. Some ionic tracers cannot be used because analytical techniques are not sufficiently accurate for meaningful interpretation. In all cases, the use of ionic tracers require the proper approvals and permits from the Department of Environmental Resources.

Before the introduction of tracers, especially ionic tracers, into the hydrogeologic environment in all study areas, detailed hydrogeologic information is imperative. Pertinent data required are a comprehensive geologic description of the surface and near-surface rocks, the aquifer characteristics of the entire zone of saturation, rates and direction of ground water flow, ground water quality, and the dispersion pattern. The volume of water in the zone of saturation apt to be affected must be calculated. The amount of tracer required to raise the concentration of the tracer to the determined level, without causing pollution, must be calculated. Post study sample monitoring programs are recommended to assure adequate dispersion of the tracer at its site of introduction.

yield, drawdown and representative aquifer samples. Pump periods lasted two to three hours per zone.

4. Drawdown recording devices were utilized on the surrounding water supply wells and core test hole during a continuous 16 day pump test on an adjacent water supply well; the continuous pump rate range between 175 - 190 gpm. The resultant constant and cumulative yield data from the pumped well and monitored drawdown data from the adjacent wells permitted the derivation of reliable transmissibility and coefficient of storage data within the case study project area.

5. A thorough program of sampling from wells, strip pits, deep mines and streams was conducted to provide complete analyses of chemical and biological water quality.

Thus the comprehensive test programs reduced many of the geologic and volumetric unknowns in the immediate case study area, and provided hydrodynamic performance data within the total zone of saturation. Therefore, the resultant parameters provided sufficient guidelines and control upon which selected tracers could be introduced to the zone of saturation.

The tracers utilized in the study were ionic tracers derived from the following manufactured chemical compounds; ammonium fluoride (NH_4F) and ammonium bromide (NH_4Br). The tracers were placed in the active strip mine, located approximately 1300 feet from the pump test well, and in a terminal entry of an abandoned deep mine located approximately 1,000 feet from the pump test well. Following the introduction of the tracers to the strip and deep mine, a continuous pump test (at a rate of 175 - 190 gpm.) was conducted for approximately 32 days. Representative water samples were obtained daily.

Subsequent analyses indicated communication between the deep mine and the test well, and between the strip mine and the test well. The strip mine tracer was the fluoride ion and was detected by a specific ion probe. The deep mine tracer was the bromide ion and was detected by neutron activation to induced radiation. The latter analyses were conducted by Mr. Kerry Uhler at Penn State University.