IDENTIFICATION OF A NEW ROCK CHARACTERISTIC FOR ECONOMIC SELECTION OF DISPOSAL SITES FOR TOXIC/HAZARDOUS MINE WASTE[1]

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Abstract - Dispersivity has been recently identified as a new rock characteristic and is considered to be a measure of the ability of a rock to allow mixing of two fluids inside a porous medium. Knowing the dispersivity of a stratum by conducting a simple, and inexpensive core test, a potentially suitable zone/stratum may be found where the toxic/hazardous waste from a mining operation can be safely disposed.

INTRODUCTION

In a surface or underground mining operation, the spoil piles and the slurry lagoons may be considered as the major sources of groundwater contamination. Where aquifers underlie these sources, water with a low pH and high total dissolved solids(TDS) can percolate to ground water and contaminate the aquifer.

The unsteady mixing of contaminated mine water discharge with the insitu fresh water in the underground porous medium is governed by the dispersion phenomenon. In a microscopically disordered porous medium, two basic mechanisms drive the dispersion process. They rise from the chaotic nature of the porelevel velocity field forced on the flowing fluid by the irregularity of the pore space (Sahimi 1986). In a disordered porous medium streamtubes get disrupted and continually break-up. These variations in lengths streamlines traversing the system are considered to be the kinematic mechanism of dispersion. As a result of changing pore geometry, orientation, and local pressure gradient of a streamline, the speed along the streamline varies considerably in traversing the medium. These two basic mechanisms cause a concentration front of fluid particles to spread as it advances through the system. The extent of the spread of the concentration front of the fluid particles depend upon the dispersivity of the medium (Dutta 1984).

Dispersion is considered as the macroscopic mixing caused by uneven flow in fixed beds of real media . A variety of mechanisms on a macroscopic scale are considered to be responsible for the observable macroscopic dispersion as indicated by Greenkorn et al. in American Chemical Society Publication (1970). Some of these mechanisms which are considered to be responsible for dispersion are listed as follows: (i) Eddy migration, (ii) Tortuosity,

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(iii) Connectivity, (iv) Flow restrictions, (v) Dead-end pores, and (vi) Adsorption.

This study was aimed at determining this new characteristic of rock, dispersivity, for different zones or formations that are encountered in surface and underground mining operations. Upon completion of the laboratory and field testing of several different tight formations, the dispersivity and the dispersion coefficient for an effectively sealing medium is expected to be established. The dispersivity or the dispersion coefficient for different formations have been determined experimentally. The sealing capability of these formations are assessed from their dispersivity value when compared to the reference dispersivity number for an effectively sealing medium. A pictorial representation of the application of dispersivity in selecting the most sealing zone in a surface mining operation is shown in figure 1. The selection process involves testing of core samples from different lithologic zones and determination of their respective dispersion coefficient and dispersivity. By comparing these values with the reference dispersivity number for an effectively sealing medium the most sealing zone is selected.

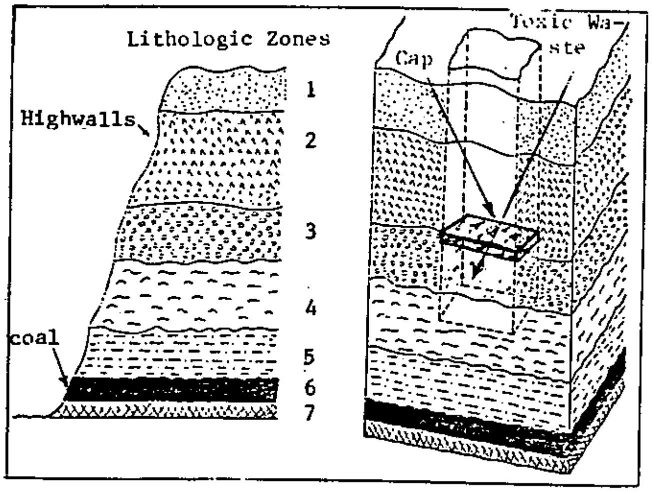

FIGURE 1.- DIPOSAL OF TOXIC/HAZARDOUS MINE WASTE IN A SELECTED ZONE

Dispersivity has been characterized as a rock property very recently by Menzie and Dutta et al.(1986). Recent research performed by these investigators at the University of Oklahoma has demonstrated that the dispersivity of a rock is as important as the permeability or the porosity in defining the characteristics of a formation.

Molecular diffusion acts as a perpetual companion of the dispersion process. It is more prominent when the displacement velocity is very low. Even in the absence of gross fluid movement, a mixing zone is found to develop (Chen et al. 1984) due to the random thermal motion of the molecules. In a displacement process, the dispersion mechanism is predominant at higher flow rates. When the interstitial velocity is large enough, then, due to insufficient time for diffusion to equalize within pore spaces, the effect of diffusion need not be considered. Perkins and Johnston (1963) have shown that for $Udp/D_o > 50$ the dispersion mechanism dominates the mixing process. Due to a relatively high flow rate used in the displacement process of the present study, the dispersion mechanism is predominant.

In this paper we will describe the experimental setup, theory and procedure used for determining dispersivity, and discuss the correlations of dispersion coefficient and dispersivity with other physical characteristics of rocks. We will also focus on the characteristics of contaminants, present day problems associated with mine waste disposal, and the applicability of dispersion coefficient and dispersivity in selecting the most sealing zone for disposal of toxic or hazardous mine waste.

EXPERIMENTAL SETUP

A schematic diagram of the experimental setup is shown in figure 2. From a block of sandstone, 1.5" and 2" diameter cores were drilled by using a coring bit. The cores were then dried in an oven for 48 hours at a temperature of 230 °F.

A new core mounting technique has been developed in this study to overcome the problems such as: leakage, channeling through interface, and pressure limitation (<30/35 psig) etc., which were faced in the conventional epoxy coating method. This new technique involves coating a core with liquid weld, (which is commercially available as J-B Weld), and heavy duty aluminum foil.

A coating of liquid weld is first applied on the core and then smoothly wrapped with heavy duty aluminum foil. The same process and sequence of coating and wrapping is repeated twice for better integrity of the coated core. The core is then uniformly rotated while being heated mildly for 2 hours and left at room temperature (70 °F) for 24 hours for complete solidification of the coating. Three pressure-holding clamps were also used on the core for safety and better manageability of the core assembly.

The liquid metal coated core is held at the ends by two aluminum end-plates. Two rubber gaskets are placed between the end plates and the core surface in order to prevent any leakage from the sides. The core assembly is then tested under water for leakage by injecting air from one end into the core. The maximum available line pressure (95 psig) is used during the leakage test. When no leak is observed the core assembly is considered ready for experimentation. However, before beginning the actual experimental run the core is again oven-dried for 48 hours and the dry weight of the assembly is first recorded at the very outset of the experimental run.

The complete experimental setup used for the miscible displacement process consists of a high pressure, variable volumetric rate, positive displacement pump, graduated cylinders, 1/8" stainless steel tubing, pressure gauge, and a wet test meter (flowmeter).

THEORY AND PROCEDURE

The basic equation governing the dispersion phenomena originates from the Fick's law of diffusion. Kramers and Alberda (1953) rationalized that on the basis of a cell-mixing model the equation for concentration in a packed tube with uniform flow can be expressed as:

$$K\frac{d^2C}{dx^2} - U\frac{dC}{dx} = \frac{dC}{dt} \quad \ldots\ldots\ldots(1)$$

where:

K = Dispersion Coefficient, sq. cm/sec.
dC = Change in Concentration.
U = Average Interstitial Velocity, cm/sec.
dt = Change in Time, sec.
dx = Change in length of the core, cm.

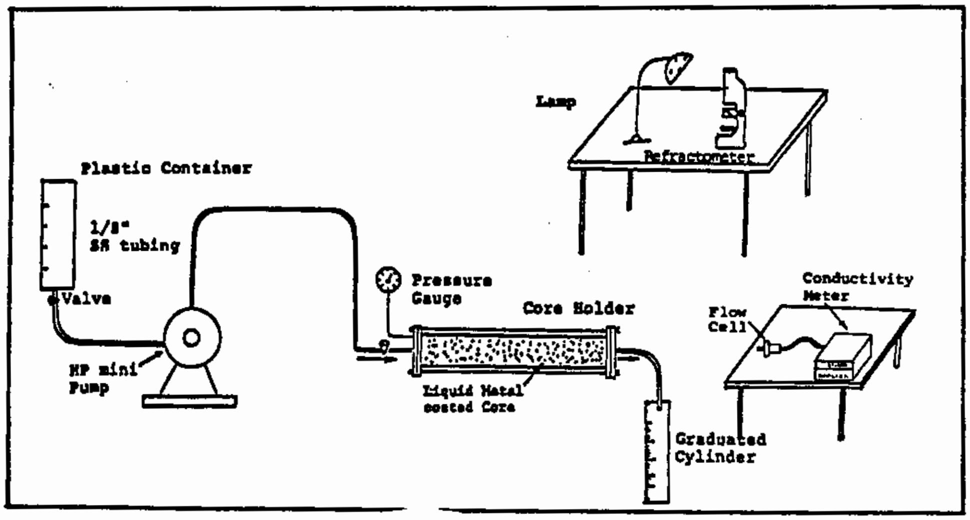

FIGURE 2.- SCHEMATIC DIAGRAM OF EXPERIMENTAL SETUP

Analytical solutions to equation (1) have been derived for various boundary conditions by Brigham (1973). For the idealized displacement, and ignoring higher order terms, the solution for solvent concentration for the above equation can be written in the form:

$$C = 0.5 \operatorname{erfc}\left(\frac{x - Ut}{2\sqrt{Kt}}\right) \quad \ldots.(2)$$

where :
x = distance along the length of the core, cm.

Because of the asymptotic behavior of the complimentary error function (erfc), it is not practical to define the mixing zone as that in which C ranges from zero to unity. Instead, it is customary to select arbitrary values of concentration, such as 0.10 and 0.90, to define the mixing boundaries. By substituting the above values for C in equation (2), we can solve for the zone boundaries as follows:

$$x_{10} = 0.9062.2(Kt)^{0.5} + Vt \ \ldots(3)$$

and

$$x_{90} = -0.9062.2(Kt)^{0.5} + Vt \ ..(4)$$

where:
$x_{10/90}$ = Distance to the 10%/90% solvent concentration.

A convenient method for determining the dispersion coefficient from the experimental data of a miscible displacement process has been shown by Brigham et al. (1961). The same method was little modified for better precision and to check back the pore volume in the present study. In this method, with a given pore volume, Vp, of the porous media, and any volume, V, during displacement through the media, a parameter λ was defined as follows:

$$\lambda = [(V/Vp) - 1)]/(\ V/Vp) \ \ldots\ldots(5)$$

A plot of λ against concentration results in a straight line, which yields the values of λ corresponding to 90% (λ_{90}) and 10% (λ_{10}) displacing fluid concentrations. The dispersion coefficient, K was then calculated from the following equation (Perkins and Johnston 1963) :

$$K = \frac{UL\ (\lambda_{90} - \lambda_{10})^2}{(3.625)^2} \ \ldots..(6)$$

where:
L = Length of the core, cm.
K = Dispersion Coefficient, sq. cm./sec

After determining the dispersion coefficient, K, from equation (6), the dispersivity, α_d was calculated by using the following equation

$$\alpha_d = K/U \ \ldots\ldots\ldots\ldots\ldots\ldots(7)$$

where:
α_d = Dispersivity, cm.

The experimental data needed to calculate dispersivity by using the equations listed above were obtained in the following manner:

The pore volume and the porosity of the core was first determined. The pore volumes of the cores were determined by complete liquid saturations of the cores. In most of the experimental runs Naphtha was used as the saturating fluid. In the matched viscosity floods Isoveg (96.75% Isooctane and 3.25% Vegetable oil) or NC9010 (90% Naphtha and 10% Crude oil) was used to saturate the cores. The clean dry cores were first weighed to get the dry weight(W1) of the cores. They were weighed again after complete saturation with the liquid to get the saturated weight (W2). The weight (W2 - W1) of the liquid in the void volumes when divided by the specific gravity of the liquid yielded the pore volumes of the cores. From the pore volumes and bulk volumes, the porosities of the cores were determined.

After determining the pore volumes and porosities, the cores were again cleaned by injecting air and drawing a vacuum on the outlet end of the cores. The cleaning process was continued until the original dry weight (W1) was obtained. The cores were then dried in the oven again. The total permeabilities of the cores were then determined for correlation purposes by using the standard Klinkenberg (1941) method. The cores were then saturated completely for displacement experimentations. The different types and lengths of cores, resident (saturating) and displacing fluids, and viscosity ratio, V (μ_r/μ_d) used in the experimental Runs are listed in table 1.

Table 1 -- Core Types and Fluids used in the experimental Runs

Run No.	Core type	V (μ_r/μ_d)	Displacing/ Resident fluid
4	Berea ss	17.12	Naphtha/Crude
5	Berea ss	17.12	Naphtha/Crude
6	Berea ss	1.0	NC9010/Isoveg
7	Berea ss	17.12	Naphtha/Crude
8	Berea ss	0.058	Crude/Naphtha
9	Berea ss	0.058	Crude/Naphtha
10	Berea ss	17.12	Naphtha/Crude
11	Berea ss	0.063	Crude/Naphtha
12	Berea ss	15.88	Naphtha/Crude
13	Berea ss	0.063	Crude/Naphtha
14	Berea ss	15.88	Naphtha/Crude
15	S.P.* ss	1.0	Isoveg/NC9010
16	S.P. ss	1.0	Isoveg/NC9010
17	S.P. ss	1.0	Isoveg/NC9010

* - St. Peter Sandstone

During the miscible displacements, the effluent concentrations of the displacing fluid were determined by measuring the refractive index of the effluent mixture and obtaining the concentration values from the calibration curves prepared prior to the displacement runs. The displacing fluid was continued to be injected until the effluent concentration of the displacing fluids reached about 95% or more.

Calculations and interpretations of data were performed by plotting the parameter λ vs. effluent concentration of the displacing fluid. A sample plot of λ vs. effluent concentration of Isoveg for Run #16 is shown in figure 3. The effluent concentration profile were also plotted against pore volumes injected for getting the pattern of displacement. A sample plot for Run #16 showing the concentration profile is shown in figure 4.

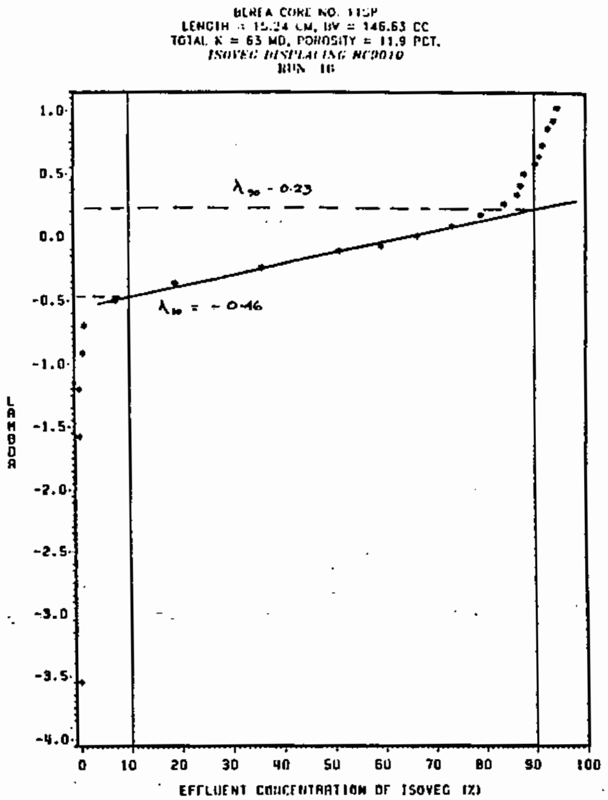

FIGURE 3.- LAMBDA VS EFFLUENT CONC.

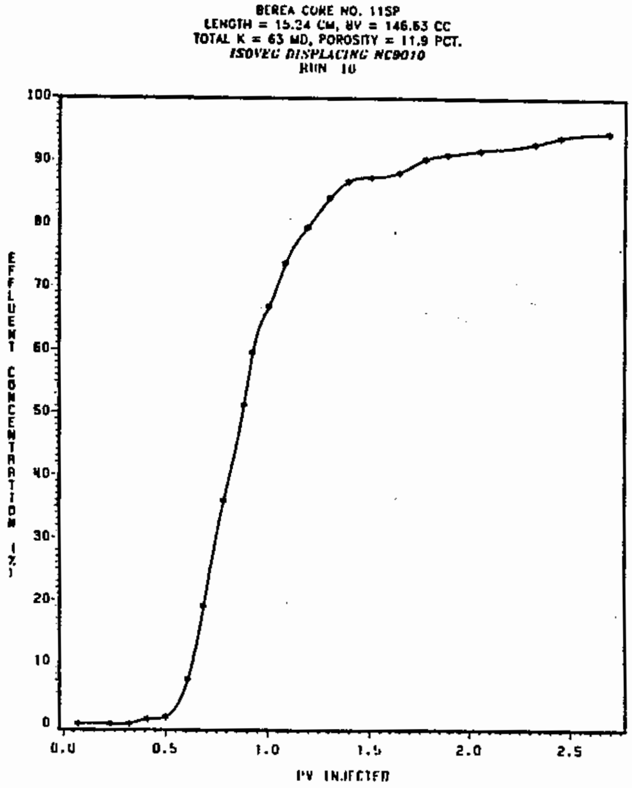

FIGURE 4.-EFFLUENT CONCENTRATION VS PV INJECTED

An alternative method used by Rumer (1962) to calculate the dispersion coefficient was also used to calculate the values of dispersion coefficient for some of the Runs in order to check the accuracy of the method used. The value of the dispersion coefficient, K, for some of the Runs calculated by Rumer's method matched within 4% of the values obtained by the λ-method used in this study.

EXPERIMENTAL RESULTS

The experimental results obtained for Run #4 through #17 are summarized in table 2. Plots of λ vs. effluent concentration profiles for Run #14, and #17 are shown in figure 5. The effluent concentration profiles for Run #14, and #17 against pore volumes injected are shown in figure 6.

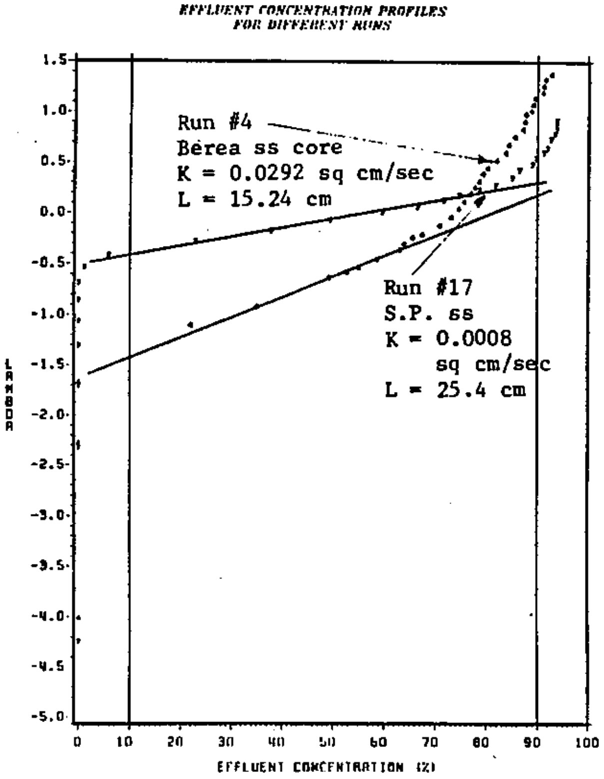

FIGURE 5.-LAMBDA VS EFFLUENT CONCENTRATIONS

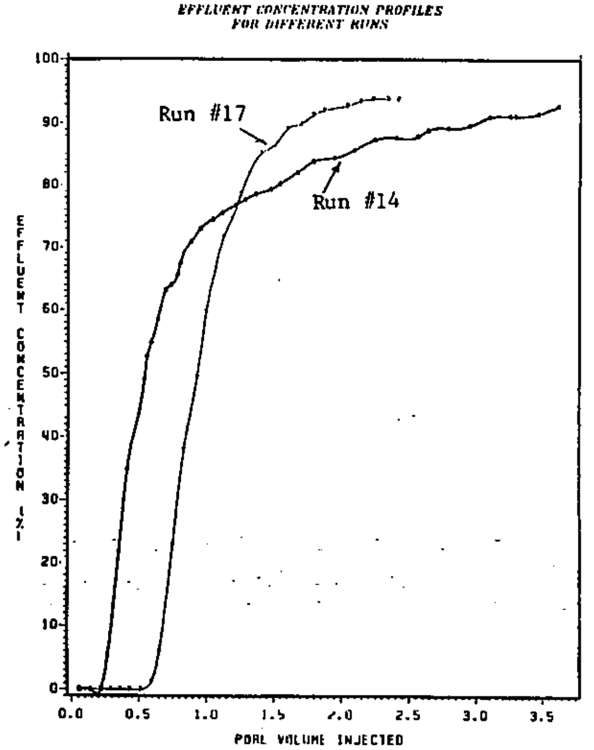

FIGURE 6.-EFFLUENT CONC. VS PV INJECTED

Table 2 -- Experimental Results*

Run #	ϕ (%)	k (mD)	α_d (cm)	K (cm^2/sec)	L (cm)	U (cm/sec)
4	22.6	225	6.17	0.023	13.97	0.0037
5	22.6	15	1.45	0.006	13.97	0.0038
6	18.1	90	0.37	0.002	15.24	0.0059
7	18.1	90	3.3	0.017	15.24	0.0050
8	18.1	90	0.07	0.0004	15.24	0.0050
9	19.6	98	0.08	0.0004	15.24	0.0047
10	19.6	98	3.39	0.017	15.24	0.0049
11	19.8	143	0.12	0.0056	15.24	0.0048
12	19.8	143	3.93	0.0196	15.24	0.0050
13	22.8	680	0.13	0.0006	15.24	0.0042
14	22.8	680	6.30	0.0292	15.24	0.0046
15	11.8	2.1	0.03	0.0005	15.24	0.0155
16	11.9	3.0	0.04	0.0006	15.24	0.0154
17	9.8	1.6	1.06	0.0008	25.40	0.0008

* – ϕ = Porosity; k = Permeability;
K = Dispersion Coefficient;
α_d = Dispersivity; L = Length of core;
U = Average Interstitial Velocity.

DISCUSSION AND CORRELATION

Permeability Correlation:

The experimental results indicate that of all the relationships observed so far between the dispersion coefficient of a rock and its other physical properties, the most conspicuous relationship is found to exist between the permeability and the dispersion coefficient.

From the experimental results listed in table 2, it may be noted that for the Berea sandstone cores the dispersion coefficient, K, and the dispersivity, α_d, increased with the permeability, k, of the cores. This observation matches the findings of Dutta (1984) and Harleman et al. (1967). Miscible flooding experiments with Berea sandstone cores conducted by displacing crude oil with naphths showed a definite linear relationship between dispersion coefficient, K, (sq cm/sec.) and permeability, k (mD), of the cores. A plot of permeability against dispersion coefficient for different experimental runs is shown in figure 7. A generalized equation governing this relationship can be written as:

$$K = a \log (k) + c \quad \text{.........(8)}$$

where:

K = Dispersion Coefficient, cm2/sec
k = Permeability, mD
a,c = constants.

For Berea sandstone with Naphtha displacing Crude oil having a viscosity ratio (μ_r/μ_d) of 17.12 this empirical equation can be written as:

$$K = 0.01487 \log (k) - 0.012 \quad \text{...(9)}$$

Similarly, values of these constants for different rocks and different viscosity ratios of the resident (u_r) and the displacing (μ_d) fluids can also be determined.

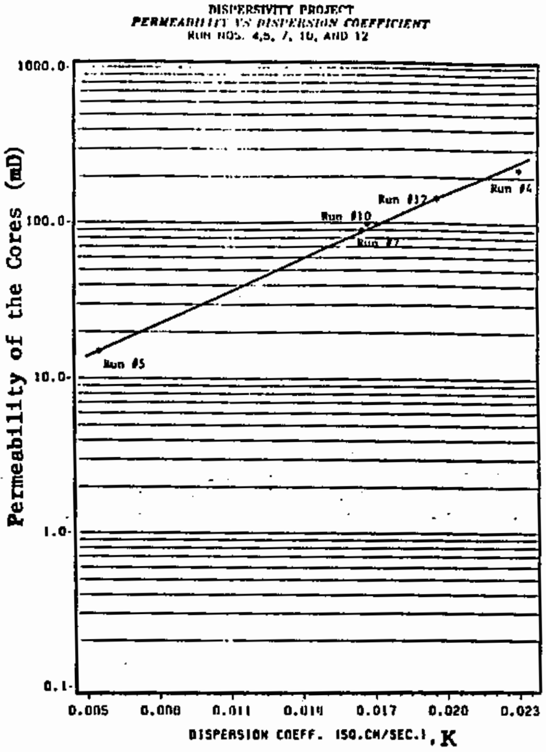

FIGURE 7.- PERMEABILITY VS. DISPERSION COEFFICIENT

Viscosity Correlation:

To obtain a standard dispersion coefficient (Ks), a viscosity ratio correction factor was introduced. A standard dispersion coefficient (Ks) is defined as the dispersion coefficient obtained from a miscible flooding process with a viscosity ratio of the resident fluid to the displacing fluid as one, i.e., when the displacing fluid and the resident fluid has the same viscosity.

During the experimental runs in a Berea sandstone core using different viscosity ratios of fliuds, different dispersion coefficients were obtained. From the results obtained the following empirical relationship was found to best match the values of dispersion coefficients.

$$Ks = K \left(\mu_r/\mu_d \right)^n \quad \text{..............(10)}$$

or,

$$Ks = K\ (\ V\ )^{n} \ \ldots\ldots\ldots\ldots\ldots (11)$$

where:

Ks = Standard dispersion coefficient, sq. cm/sec.
K = Dispersion Coefficient at any given viscosity ratio, sq. cm/sec.
V = μ_r / μ_d
$\mu_{r/d}$ = Dynamic viscosity of resident/displacing fluid.
n = empirical constant exponent.

For the Berea core having a permeability of 90.0 mD, the value of the exponent 'n' was determined to be -0.71. The change in the value of this exponent 'n', if any, with rocks of different physical properties is under investigation. Equation (11) can thus be written as:

$$Ks = K\ (V)^{-0.71} \ \ldots\ldots\ldots\ldots (12)$$

Actual value of standard dispersion coefficient, Ks, for a Berea sandstone core was obtained by a miscible displacement with matched viscosity (V = 1) in Run #6. The values of Ks for the same core in other Runs (#7, and #8) with unmatched viscosity ratios were calculated by using equation (12). The calculated values of Ks matched closely with the actual, experimentally determined, value of Ks.

In the same manner, if the standard dispersion coefficient, Ks, is known, the dispersion coefficient, K, for any given viscosity ratio, V, can be calculated by using equation (12).

Selection of Disposal Sites:

Characteristics Of Contaminants -

The principal ground-water contaminants from mine waste are acidity, dissolved solids, metals, radioactive materials, color, and turbidity (Miller 1980). While many of the contaminants are not toxic, they can be present at levels in excess of U.S. Public Health Service and EPA drinking water standards (USDH 1962).

The most prevalent contamination problem associated with coal mining is the formation and discharge of large volumes of acid. Acid formation will occur when precipitation brings water into contact with pyrites (metallic sulfide). The exposure of pyritic minerals to air and water results in their oxidation to form sulfuric acid. Beyond the basic chemical relationship between pyrites, oxygen, and water, it is suspected that the acid formation may be influenced by complex biochemical reactions involving one or more types of bacteria. Although not completely dependent upon acidity, the solubility of metals varies with pH, and acidic runoff and seepage may contain high metal ion concentrations.

The oxidation of pyrite in the presence of water results in generation of both sulfuric acid and ferrous sulfate. The sulfate levels in coal mine drainage and in the receiving aquifers may be as high as several thousand ppm and are quite commonly in excess of the recommended limit of 250 ppm. This limit has been set for reasons of taste; water containing higher concentrations can be safely consumed although certain sulfate salts function as laxatives.

Following the initial oxidation of pyrite and the production of ferrous sulfate, subsequent oxidation will normally produce a ferric sulfate. The end result is the release, in associated aquifers, of substantial quantities of iron at concentrations in excess of the recommended limit of 0.3 ppm (USDH 1962). Iron at this level is not harmful to health, but it tends to impair taste and discolor water under certain conditions. Precipitates of iron and related iron bacterial colonies can clog plumbing, water transmission lines and water-supply wells. High levels of dissolved iron are commonly noted in ground water that has been contaminated from coal mining activities as reported by Miller (1980).

Acid dissolves many minerals, producing soluble salt solutions. In this way, the dissolved solids concentration can become quite high. Metals frequently associated with metallic ore deposits such as copper, zinc, cadmium, and manganese also are dissolved by acid mine drainage. The combination of acidity, high dissolved solids concentration, and metals makes the presence of the acid mine water very undesirable in either surface or ground water (Miller 1980).

In regions where mining proceeds in alkaline rocks, such as limestone, dissolution of the rock may produce water with a high pH. Basic mine water has a relatively low complement of heavy metals because most form insoluble salts under conditions of high pH. However, the water can still be highly mineralized. Calcium and magnesium ions are frequently found in significant concentrations, making the water hard.

Although carbon is the most important element found in coal, as many as 72 other elements have been associated with some deposits. The ash formed by bituminous coals of West Virginia consists of about one percent each of sodium, potassium, calcium, aluminum, silica, iron, and titanium. In addition, 26 metals were present in trace amounts, including lithium, rubidium, chromium, cobalt, copper, gallium, germanium, lanthanum, nickel, tungsten, and zirconium (Longwell 1969).

Methane and hydrogen sulfide are quite commonly found in the geologic formations associated with coal as well as in the various disposal areas; waters in the vicinity of coal mines may be highly charged with dissolved gases (Collier 1964).

In many metal mining operations, the ore contains a large amount of worthless rock that must be separated from the mineral before the ore can be smelted or refined. This process of concentrating the ore, known as beneficiation, is usually performed at the nearest possible site to the mine to eliminate costly transportation of unwanted rock. The most common concentrating techniques are flotation and acid separation (Miller 1980).

The waste from concentrating operations, referred to as tailings, can be in solid or liquid form. The solid is composed of minerals associated with the metallic compound being beneficiated. As an example, the waste from a typical copper beneficiating operation contains quantities of lead, zinc, gold, and silver; smaller amounts of arsenic, antimony, bismuth, selenium, tellurium, nickel, cobalt, and cadmium; and trace quantities of germanium, indium, tin, and thallium. 8) Solid waste from the beneficiation of other metallic ores contains many of the same substances. Liquid waste from beneficiating operations contains water and acids (usually nitric or sulfuric), in addition to the minerals associated with the solid tailings. Thus, waste from the concentrating phase of ore processing contains large quantities of toxic substances and can be a serious source of ground-water contamination.

Underground and surface uranium mining practices have been found to greatly increase the concentration SSof dissolved radium-226 in ground water. This is believed to be the result of: (i) exposure and oxidation of the ore body, and (ii) contact of mine drainage water with spilled ore and wastes within the mine(Kaufmann et al. 1975).

Present Day Problems -

Disposal of toxic mine wastes pose a big problem to the operator in both surface and underground mining industry. These wastes can not be disposed by the normal disposal systems, such as, slurry lagoons, and tailings etc. Operators have to transport the toxic/hazardous wastes to an EPA/USDH-approved disposal sites for that specific type of waste. Even, lubricants, and other oil-spills from the mine shops have to be transported to an approved site for disposal. Most of the toxic wastes generated in eastern and northeastern Oklahoma are taken to Tulsa, Oklahoma or outside the state for disposal. Similar problems are faced by many other operators elsewhere in the U.S.

In an attempt to resolve this problem the authors suggest that if a sealing zone could be identified in the overburden (OB) or underburden (UB) strata of a strip mine, then the toxic waste could be safely disposed in that strata and capped/cemented on the top as shown in figure 1. The wastes disposed in this manner will not contaminate or reach the groundwater.

Core samples may be taken from the highwalls (figure 1) and their dispersion coefficients and dispersivities determined by using the techniques described in the previous sections of this paper. For example, out of the 5 OB and 1 UB strata (figure 1), if zone #3 is found to have a standard dispersion coefficient, Ks3, of 0.1e-06 sq. cm/sec, then it may be considered as one of the sealing media in the tested OB and UB zones. If the dispersion coefficients of any of the strata do not fall below 1.0e-06 sq. cm/sec, then it may be inferred that no sealing medium exists amongst the tested OB and UB strata. The reference standard dispersion coefficient number for an effectively sealing medium is yet to be established. Investigations are being continued presently on some OB and UB core samples from the "Dixie Girl" zinc mine (presently inactive) in Marion County, Arkansas, for better understanding of an effectively sealing medium. Continuous core samples have been taken from this mine area. The samples include cores from the Plattin formation, St. Peter sandstone, Newton sandstone, and Everton dolomite. A few samples from the St. Peter sandstone have been tested so far. They were found to have dispersion coefficients ranging from 5.0e-04 to 8.0e-04 sq. cm/sec.

CONCLUSIONS

A standard technique for determining the dispersion coefficient and dispersivity has been developed in this study. By using the dispersion measurement techniques as described in this paper, the extent of unsteady mixing of the contaminated mine water discharge with the underground fresh water can also be determined for different OB and UB zones.

The diapersion coefficient and the dispersivity value of different OB and UB strata from any strip mine operation can be experimentally determined by using the proposed technique as described earlier in this paper. Thus, by comparing the dispersivity value of different OB and UB strata with the predetermined dispersivity of an effectively sealing medium, the extent of sealing capability of each OB and UB zones will be determined.

The advantages of using the dispersion characteristics of a rock over the permeabilities are summarized below:

(i) Permeability of a rock varies with the types of fluids injected. For example, permeability of a Berea sandstone core to water may be about 45 mD, whereas the permeability of the same core to crude oil may be 10 mD. With the viscosity correction factor, the standard dispersion coefficient of a core was found to be the same, even when different fluids were used to conduct the displacement experimentatiions.

(ii) The experimental determination of dispersivity is much simpler and easier than the measurement of absolute permeability of a rock. Also, no permeability measurements are necessary for determination of dispersivity.

(iv) Permeability is inversely proportional to the pressure drop, and is completely pressure dependent. Dispersivity is independent of the pressure and velocity. However, flow rate has some bearing on dispersion coefficient.

While pursuing for a standard technique, a new metallic method of coating the sample cores for laboratory studies has been developed during this investigation.

Dispersivities of several berea sandstone cores were experimentally determined and attempts were made to correlate dispersivity and dispersion characteristics with other rock characteristics. The most significant and direct relationship of the dispersion characteristics was found to exist between the dispersion coefficient and the total permeability of a core.

A correlation has also been developed to correct the viscosity effect of the displacing and the displaced fluid on the dispersivity of a reservoir rock.

Amongst a few other correlations being attempted presently, Koval's (Koval 1963) heterogeneity factor, H-factor, for the Berea sandstone cores also showed some particular trend of variation with the corresponding dispersivities and dispersion coefficients.

Experimental results are also being obtained on several core samples in order to investigate the impact of other physical properties of the displacing and the resident fluids used in the miscible flooding experiments for determination of dispersivity, and the dispersion coefficient. Several physical characteristics are also being measured on the same core samples for testing other possible relationships with dispersivity. The ultimate goal of this investigation is to determine the dispersivities and standard dispersion coefficients of various OB and UB strata, which are commonly encountered in surface and underground mining operations and to establish a reference dispersion coefficient number for an effectively sealing medium.

NOMENCLATURE

A = Cross sectional area, sq. cm
dp = Particle diameter, cm

C = Concentration
D_o = Diffusivity, cm2/sec.
D = Molecular diffusion coefficient, sq. cm/sec.
H = Heterogeneity factor
K = Dispersion coefficient, cm2/sec.
k = Permeability, mD
q = Volumetric flow rate, cc/sec.
L = Length, cm
S = Saturation, % of pore volume
t = Time, sec.
T = Temperature, oF
U = Average Interstitial Velocity, cm/sec.
V = Volume injected, cc
Vp = Pore Volume, cc

Greek Letters:

α_d = Dispersivity, cm
ϕ = Porosity, %
$\lambda = [(V/Vp) - 1]/(V/Vp)$
μ = Dynamic viscosity, cp

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