$\mu$ = viscosity;

$\lambda$ = dimensionless coefficient in Eq. 3; and

$\lambda$ = dimensionless coefficient in Eq. 8.

$\phi$ = prosity

$\gamma$ = specific gravity

## AppendixII. – References

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and the downdip front velocities of the injected waste or fresh water in a saline aquifer, may give a reasonable answer in regards to the migration of the bubble.

2. In order to use Eq. 8, a coefficient $\lambda$ should be found. This coefficient is related to the density ratio, aquifer thickness, radius of the injected fluid and the porosity of the aquifer. The coefficient $\lambda$ may be obtained from a set of curves, provided by experimental analyses, for different density ratios and dip angle on a thick aquifer,

3. The results of this work are applicable to the other miscible displacement process, whenever in a dipping aquifer a density difference between the injected and the native fluid exists.

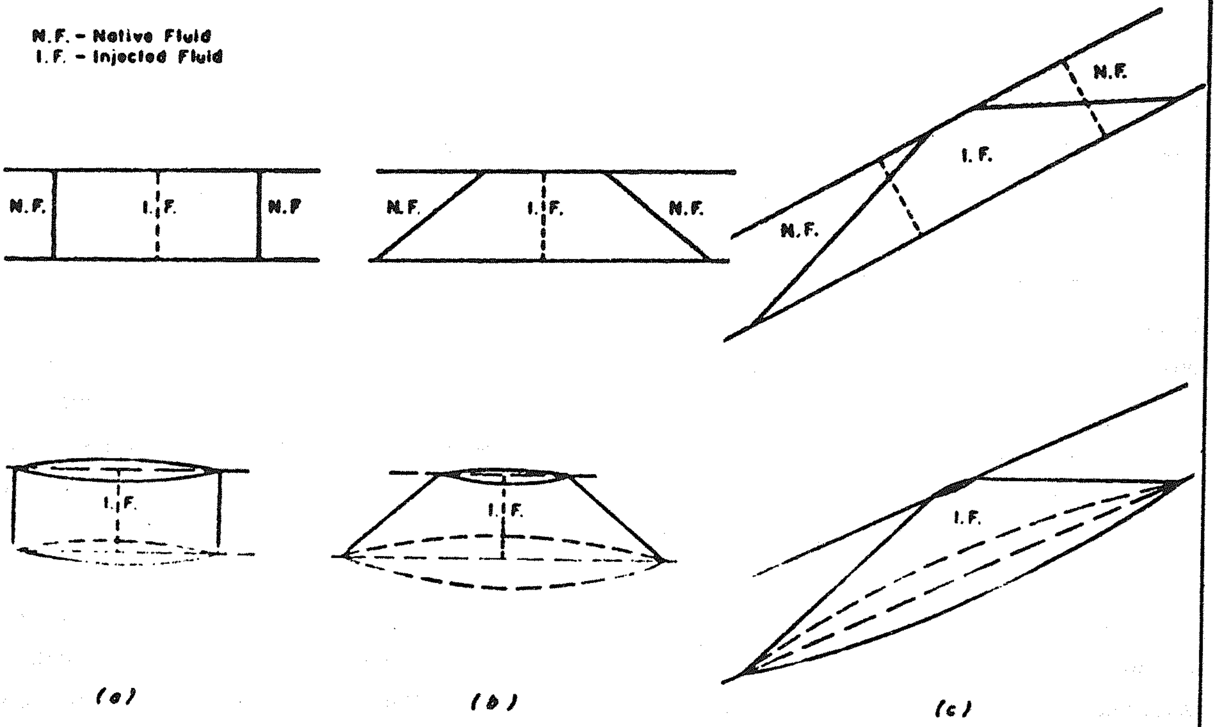

Fig. 1. Schemmatic of fluid injection in a confined aquifer

Appendix I . – Notation

The Following symbols are used in this paper:

$F_b$ = buoyant force;

$F_\mu$ = viscous force;

g = gravitational acceleration;

h = aquifer thickness;

k = permeability;

$K_i$ = hydraulic conductivity or $k_i \gamma_i / \mu_i$

m = dimensionless coefficient in Eq. 2;

r = radius of the injected fluid;

$r_e$ = distance to the isopotential line;

$V_c$ = velocity of the center of the injected bubble;

$V_d$ = downdip velocity;

$V_l$ = velocity of lay–down at the front position of the bubble at zero dip angle;

$V_{ld}$ = velocity of the lay–down at downdip front at x dip angle;

$V_{up}$ = updip front velocity;

$\rho_i$ = density of the injected fluid;

$\rho_n$ = density of the native fluid;

$\tau_p$ = shear stress;

The coefficient, m, must be determined experimentally. The shape of the injected bubble will change in the course of movement, therefore, it seems that the coefficient, m, may be regarded as a function of the shape of the injected fluid as well as aquifer characteristics.

Assuming that;

$m=f(k, r, r_e, h)$ . . . . . . . . . . . . . . . . . . . . . . . . (3)

It may be expected that as the permeability, k, increases, the coefficient, m, and consequently the viscous force decrease, however, the coefficient, m, and viscous force increase with an increase in the area of contact at ceiling or floor of the aquifer. The relationship between coefficient, m, and other factors, h and $r_e$, is not clear. But as the thickness of the aquifer h appears in Eq. 2, it may not be necessary to assume any relation between the coefficient, m, and, h.

In order to evaluate the effect or $r_c$ on the migration of the injected fluid some experimental runs were made, and results indicated that the relative size of the injected bubble to the distance to isopotential boundary $r_c$ has a negligible contribution. In other words, the results show that except for relatively small injected bubble size, the updip and the downdip front velocities remain constant even when the distance to the isopotential line increases.

Mathematically, if the effect of h and $r_c$ can be ignored, then the coefficent $m = f(1/k, r)$. But it is difficult, if not impossible, to find an exact relation between the coefficient, m, and k and r. Therefore, by introducing another coefficient, $\lambda'$, a new relation may be derived.

$m = (3\pi r^2/k)(1/\lambda')$ . . . . . . . . . . . . . . . . . (3)

where, $3\pi r^2$ is the bottom area of the injected fluid at the break through point, when the injected fluid becomes a cone with its apex at the roof of the aquifer. It should be noticed that for a lighter injected fluid, the area of the roff may be considered at break through point, more simply

$m = (r^2/k)(1/\lambda)$ . . . . . . . . . . . . . . . . . . . . . . (4)

where $\lambda = \frac{\lambda'}{3\pi}$. By substituting the right side of Eq. 1 and 2 for a constant velocity of the injected bubble, assuming $\rho i/\rho n$, the velocity of the migration of the injected fluid becomes

$V = \lambda (k\gamma_i/\mu_i)(h/r)^2\ (1-\rho n/\rho i)\,\phi \sin\alpha$. . . (5)

and if

$\omega = (h/r)^2\ (1-\rho n/\rho i)\emptyset$ . . . . . . . . . . . . . . .(6)

$k = (k\gamma_i/\mu_i)$ . . . . . . . . . . . . . . . . . . . . .(7)

therefore

$V = k_j \omega \lambda \sin\alpha$ . . . . . . . . . . . . . . . . . . . .(8)

The velocity of the injected fluid expressed by Eq. 8 includes the viscosity of the injected fluid, which means that the injected fluid is moving in an idealized native fluid and there is no friction between the displaced native fluid and the injected one. This phenomenon can be interpreted if you assume that there is no flow separation around the injected bubble and that there is equal potential in the front and rear of the bubble.

Eq. 8 may be used for determination of the updip and the downdip front velocities and the proper coefficients of $\lambda$ or updip and downdip, are experimentally obtained. Furthermore, this equation satisfies the following conditions: (1) for $\alpha = 0$, or $\rho i/\rho n = 1$, as anticipated, the updip and the downdip front velociti are zero; (2) when $\rho i/\rho n > 1$ or $\rho i/\rho n < 1$, the injected bubble migrates downdip and updip respectively; and (3) for $\alpha = 90$ degrees, the downdip and updip front velocities are equal and maximum.

## Conclusion:

As the result of this study, the following conclusions may be drawn, with respect to the migration of injected fluid in an isopotential confined dipping saline aquifer.

1. Eq. 8, which is derived to predict the updip

location of the injected waste bubble may be predictable.

## Theory:

Background— Storage of fresh water in a confined saline aquifer is a miscible displacement process, and it is affected primarily by such factors as: (1) molecular diffusion and convection dispersion; (2) aquifer dip; (3) gravity segregation (bouyancy force); (4) pre-existing groundwater flow; (5) viscosity difference between native and injected fluid; and (6) density difference between native and injected fluid.

The following assumptions have been made and run experimentally: (1) the viscosity of the native and the injected fluids are equal or, in other words, there is no viscosity difference between two fluids; (2) there is no pre-existing groundwater flow; (3) the injection occurs in a piston-like displacement process; (4) the movement of the injected fluid is a laminar flow; (5) the injected bubble moves totally within a circular isopotential field; and (6) the aquifer is homogeneous and isotropic.

In reality, the viscosities of the injected and the native fluids are not necessarily the same, but as will be shown later, the first assumption does not restrict the theoretical concept and engineering application of this work. In the field, as regards to the second assumption, a circular isopotential field may be produced by using a bounding well system (9), and the velocity of the injected fluid is low enough so that assumption of the laminar flow is satisfied.

In the study reported upon here, the following parameters have been of major concern and their effects investigated: (1) the effect of density difference and the dip angle on the migration of the injected fluid, and (2) the effect of bubble size of different density ratios on the movement of the injected bubble.

Fig .1b indicates that, even with zero dip angle, the gravitational segregation, due to density difference of the injected and the native fluid, will cause a distorted cone with a mixed zone of two fluids. In Fig. 1c, the effect of dip on gravitational segregation and the movement of the injected bubble due to density difference, in downdip and updip fronts, has been depicted. As time goes on, the geometry of the injected fluid, in the three dimensional case, undoubtedly becomes complicated.

In the field, if the injected waste is heavier than the native fluid, the major concern would be to trace the downdip front of the base of the injected fluid. In case of injection of lighter fluid, such as fresh water injection in a saline aquifer, the recovery efficiency depends on the updip movement of the bubble and again the downdip front trace may be useful.

For these reasons, from a practical point of view, the actual updip and the downdip front velocities of the injected fluid were computed from the bottom traces. If the ceiling traces are needed, they maybe obtained by using the method described by Kimbler, et al. (7).

## Mathematical Solution:

In the movement of the injected fluid in a dipping aquifer with a horizontal isopotential surface, the two dominant, the bouyancy and viscous forces considered.

1. The bouyancy force, which is the effect of the density defference of the native and the einjected fluid, may be expressed as;

$$F_b = (\pi r^2 h \Delta\rho \ g \sin \alpha)\phi \qquad (1)$$

If $\rho i/\rho n > 1$, the injected fluid moves downward in the case of $\rho i/\rho n < 1$, the injected bubble will tend to migrate in an upward direction.

2. Viscous forces, acting against the buoyancy force, may be written in the following form;

$$F_\mu = m\tau\ A = m\ \mu(v/h)\ \pi r^2 \qquad (2)$$

# THEORETICAL SOLUTION OF THE INJECTED FLUID MIGRATION IN EXISTING AQUIFER

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**KEY WORDS:**

Subsurface Storage; Underground Injection; Waste Injection; Fresh Water injection; Miscible Displacement; Ground water Flow; Migration of Waste; Waste Disposal; Deep Well Disposal;

## ABSTRACT

The needs for fresh water storage or industrial waste disposal in deep confined aquifer have rapidly increased in recent years.

The feasibility of subsurface storage has been investigated and improved, (2,7,8), although many problems remain to be solved. Although the migration of the injected fluid occurs with a very low velocity, after a long period of time, the displacement of the injected fluid becomes significant. In fact the migration of the injected bubble will reduce the recovery efficiency of the cyclic fresh water storage, or the industrial waste disposal will appear at the ground surface or infiltrate into the downstream rivers or off - shore.

At the present time; there is no simple method to explain, overall, the complexity of the migration of the injected fluid which is created by the density and viscosity differences, dip angle and pre-existing groundwater flow.

However, the effect of different parameters may by evaluated, if some of them are kept constant.

It is for this reason that a mathematical formula is derived to determine the effect of dip on updip and downdip velocities of the front of injected fresh water or waste fluid in a confined saline aquifer.

The analyses has been made with the implication of non-per-exisisting groundwater flow and viscosity difference eliminated or held constant.

The formula involves a dimensionless coefficient which is related to the aquifer characteristics and fluid properties, and it must be determined experimentally.

As the migration of the fresh water or the industrial wastes in a saline aquifer can be evaluated, its effect on the recovery efficiency of fresh water or the

the heme pigments (myoglobin and hemoglobin). The number of reactions which these molecules are involved in are not many, but they are governed or produced in a wide variety of conditions. In fresh meat, pigments responsible for purplish–red, red and brown color are due to formation of deoxy–, oxy–, and met–myglobin, however, pink color of the processed meats such as bologna is due to formation of nitric oxide myoglobin. Importance of myoglobin as the main pigment of meat is discussed as well as formation and interconversion of some common myoglobin derivatives.

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## Magnetized Plasma Heating

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The mixing of two parallel or antiparallel beams of circularly polarized microwaves propagating in the extraordinary mode along a uniform, static magnetic field is examined. Resonant excitation of longitudenal electron plasma waves at the beat frequency is found to enhance the microwave absorption. An analysis is based on Maxwell's equations and momentum equations for the electron gas with both collision and temperature effects included. Formulae for the average power absorption density and the absorption efficiency are derived. The results of a numerical study of the coupling constant and the efficiency are presented.

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## Application of "SUMT" Algorithm in Economic Dispatch

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In this paper the non linear Programming Algorithm called SUMT (Sequential – Unconstrained – Minimization Technique) is used to solve the Economic Dispatch Problem in Electrical Power Systems.

In this studies both lossy and lossless systems are examined.

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## Theoret- u. praktische Berechnung einer Kuppungsscheibe

**Dr. Ing. (Univ. Doz.) Mehdi Akhlaghi**
Amirkabir Universitaet

Im vorliegenden Bericht wird zunaechst die theoretischen Beziehungen zur Berechnung einer Pkw- Kupplungsscheibe aufgestellt. Anhand einfacher Annahmen, die ja von der Wirklichkeit nicht sehr weit liegen und dem praktischen Fahrbetrieb entsprechen, werden die Differentialbeziehungen zur einfach loesbaren Gleichungen umgewandelt.