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DEEP WELL INJECTION OF INDUSTRIAL WASTE IN TEXAS

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ABSTRACT

Over 12.5 million cubic meters of liquid waste are generated annually in Texas and disposed of in surface impoundments. Many of these facilities are located in climatic and geologic provinces that are not suitable for surface waste disposal. Numerous cases of ground-water contamination have occurred. One alternative to surface disposal is subsurface injection. The technique of subsurface injection has existed for over 40 years, although chemical wastes have been injected in Texas for only 25 years.

The risks of subsurface injection must be evaluated by a multi-disciplinary approach. Alternate treatment technologies, pre-treatment facilities, well construction practices, and reservoir conditions must all be reviewed prior to injection. After an evaluation of each factor, the potential risks must be balanced against the benefits of injection.

Numerous geologic formations exist in the State of Texas that are suitable for waste injection. These formations are of large areal extent and range in age from Mississippian to Miocene. The largest number of injection wells are in the Gulf Coast area, where the petrochemical industry is concentrated. These wells are normally completed below 1500 meters subsurface depth in Miocene age, unconsolidated sediments. Permeabilities in these sediments frequently exceeds 10 M^3/M^2/day.

INTRODUCTION

In the last 15 years, there has been a growing public awareness of the environmental problems which have been created by our advanced technology. The results of these advances are apparent: increased life expectancy, shorter work hours and more leisure time. However, as more industries have been created to cater to this way of life, a corresponding increased volume of waste has been generated. Most treatment methods for industrial waste result in sludges, filter cake, air particle emissions, or other bi-products which must be contained or isolated. Few treatment or disposal systems exist which can remove the wastes from the biosphere.

HISTORY OF SUBSURFACE INJECTION IN TEXAS

Subsurface injection of fluids has existed in Texas for over 40 years. The first systematic use of injection probably occurred in an East Texas oil field cooperative project around 1938, which involved the injection of produced salt water back into the oil producing zone. Isolated, single well injections of oil field brine were reported to have existed 10 years before this project. Gradually, underground injection of waste as a disposal alternative became recognized by other types of industries, and by 1960, several chemical companies had operational, industrial waste injection systems.

In 1961, in order to assure the protection of groundwater from the injection of waste into the subsurface, the Texas Legislature enacted the Injection Well Act, which was later amended as the Disposal Well Act, and is now codified in Chapter 27 of the Texas Water Code. This statute prescribes the permitting system for subsurface disposal of industrial waste and produced oil field brine. Although the technique of injection was largely developed in the oil field, the regulatory programs concerning this type of disposal have been directed toward the industrial wells. Texas was the first state in the United States to enact a law regarding industrial waste wells, and the current U. S. Environmental Protection Agency program is similar to the Texas program.

NEED FOR INJECTION WELLS

Texas is a very industrialized state. During 1978, the Texas chemical industry produced over 15 million metric tons of industrial waste (ref. 1). Of that amount, 12.4 million cubic meters were liquid in nature and were disposed of in surface impoundments (ref. 2). Most industrialized areas are located in climatic and geologic provinces that are not suitable for surface disposal of liquid waste. As a result, numerous instances of surface and ground-water contamination have occurred. Recent State and Federal legislation has decreased the use of surface impoundments, and alternate disposal methods must be developed.

RISKS VS BENEFITS OF INJECTION

The risks versus the benefits of subsurface injection must be evaluated by a multidisciplinary team. Subsurface injection systems, if not properly designed and operated, can cause pollution of fresh ground-water resources. There are several ways that contamination can occur: (1) Improperly designed systems can result in corrosion of the protective casings and tubing, and leakage into fresh water can occur. (2) Once the waste has entered the intended reservoir, far below all fresh water, it can escape by upward migration along faults, fractures, or abandoned oil/gas wells. Because of the magnitude of exploratory holes drilled in Texas, the most likely method of escape is upward migration through inadequately plugged, abandoned oil or gas wells. This possible avenue of escape can be enhanced if the reservoir selected for injection has insufficient permeability and areal extent to accept the waste without significant pressure increases.

The risk of contamination resulting from injection can be reduced if sufficient geologic information is developed concerning the proposed site, if the well is properly cased and completed, and the operation is conducted in a prudent manner. Detailed evaluations and modern designs have made deep well disposal an environmentally sound method of disposal in the State. A well planned and operated injection well facility permits the removal of selected hazardous wastes from the biosphere and isolates them in deep geologic provinces. Since 1961, over 159,000,000 cubic meters of waste have been injected in Texas (ref. 3).

AVAILABILITY OF GEOLOGIC HORIZONS FOR INJECTION

Numerous geologic formations exist in Texas that are suitable for waste injection. These formations are of large areal extent and range in age from Mississippian to Miocene. Generally speaking, most geologic basins with thick accumulations of sediments have reservoirs suitable for disposal.

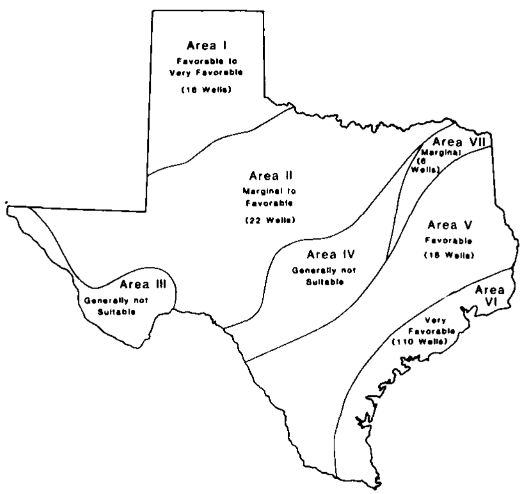

Fig. 1. Location of waste disposal wells in Texas.

Based on a geologic map of Texas and a review of numerous geophysical logs and drill stem tests, general areas of potential locations for safe injection programs have been developed (Figure 1). Selected data for these reservoirs are contained in Table 1. From 1961 to September, 1980, 174 permits for industrial waste injection wells were issued. The distribution of the wells within the State are indicated on Figure 1. The largest number of these wells is in the Gulf Coast area where the petrochemical industry is concentrated, and fortunately where many geologic horizons exist for injection. The wells in the Gulf Coast are normally completed below 1500 meters subsurface depth in Miocene-Oligocene age, unconsolidated sediments. Permeability in the Lower Miocene-Oligocene (Frio Formation) frequently exceeds $10M^3/M^2$/day.

TABLE 1
Characteristics of disposal zones in Texas

Formation	Lithology	Area of the State	Approx. Depth(ft)	Aver. % Porosity	Average K(md)*	TDS**
Granite wash	Chert	I	5300-5500	14		26,900
Hunton	Limestone	I	5700-5800	29		30,600
Simpson	Sandstone	I	6000-6200	19		167,000
Ellenburger	Dolomite	II	6100-6300	10	100	131,000
Mississippian Reef	Bioherm	II	3800	5	525	86,000
Yegua	Sand	V	3400-4500	30	300	70,000
Catahoula	Sand	V	3700	31	815	60,000
Frio	Sand	VI	5800+	30	2000	90,000
Miocene	Sand	VI	3000-6000	30	1000	70,000
Woodbine	Sand	VII	2500-5000	30	2000	12,000

* Millidarcy.
** Total Dissolved Solids milligrams per liter.

DEPENDABILITY OF INJECTION SYSTEM

In addition to minor engineering failures (corroded casings, tubing failures, etc.), several injection wells have developed injectivity problems associated with incompatibility between the injected waste and the reservoir matrix or formation water. Generally, these types of problems can be divided in three areas: matrix-waste incompatibility, formation water-waste incompatibility, and auto reactivity of the waste under bottom hole conditions. These problems are generally of no environmental concern.

Auto reactivity

Many of the organic chemical waste products are temperature and pressure sensitive. The increase in temperature and pressure from the surface of the ground to the injection zone can result in precipitation of salts or compounds. These suspended particles can result in plugging of the formation face. This type of damage is generally reversible by back flowing the well.

Waste-water-formation water reaction

Frequently, injectivity problems are caused by the precipitation of alkaline metals such as barium, calcium, magnesium, and strontium as insoluble carbonates and sulfates.

Table 2 is a chemical analysis of Lower Frio Formation water and indicates significant quantities of these alkaline metals. Injection of waste streams with any significant amounts of sulfate will cause precipitation to occur. Frequently, this problem can be averted by injecting a solution which is not reactive with the waste

TABLE 2

Chemical analysis of water from the Frio Formation, Harris County, Texas

Silica	29	Carbonate	10	Barium	43
Calcium	1850	Chloride	60140	Boron	25
Magnesium	440	TDS	124,900 mg/l	Cadmium	<0.03
Potassium	1590	pH	4.92	Iron	13
Sodium	34500	Fluoride	0.8	Manganese	1.5
Bicarbonate	150	Sulfate	11	Strontium	103

All analyses in milligram/liter except pH.

and the formation water. This "buffer" zone can separate the two uncompatible waters and keep them from mixing. In addition, many anti-scaling additives are available which can be added to the waste to prevent or retard precipitation.

Waste stream - rock matrix reactions

In area VI of the State (Figure 1), the injection interval is normally an unconsolidated sand which frequently contains interstitial clay minerals dispersed throughout the sand matrix.

TABLE 3

X-Ray analysis of core samples (upper Frio Formation)

Mineral	Range of Percent of Particle Size		
	Sand	Silt	Clay
Montmorillonite	0	0- 7	1-12
Illite	0	1- 5	1-9
Kaolinite	2-6	23-42	39-75
Quartz	69-93	18-48	11-24
Feldspar	2-27	2- 8	2-11
Calcite	.3- 6.4	2-11	2- 7

The principal mineral of the injection interval is quartz, which is non-reactive for all practical purposes. However, the sensitivity of the clay minerals increases as the total dissolved solids of the waste decreases, and injection of many organic waste with low concentrations of inorganic salts can greatly reduce the formation permeability by swelling the interstitial clays.

In recent years, industry has recognized the complexity of injection systems and compatibility testing of wastes prior to injection has become a common practice. As a result, waste injection systems have become more dependable.

SUMMARY

Since 1961, 159,000,000 cubic meters of waste has been injected into deep saline aquifers in Texas. Although there have been numerous injection well problems, none have resulted in significant risks to the environment. The failures which did occur were the result of poor planning or operational error. In recent years, the multi-disciplinary planning approach has been utilized and failures attributed to poor planning have decreased.

REFERENCES

1 Texas Department of Water Resources, Solid Waste Management Plan For Texas 1980-1986, Limited Publication LP-137, November 1980, p 10.
2 Texas Department of Water Resources, Master File of Waste Generators, Austin, Texas.
3 Texas Department of Water Resources, Open Files of Waste Injection Wells.