LIQUID WASTE MANAGEMENT USING UNDERGROUND INJECTION TECHNOLOGY

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INTRODUCTION

Today in Argentina, industry is forced by government to meet quality standards for water effluent discharged to protected waters. This policy requires treatment of the effluent prior to discharge or effluent management so that it does not enter protected waters. Liquid waste management is most important in process and extraction industries such as paper, organic chemicals, petroleum and steel industries.

Negative characteristics of industrial wastewater include oxygen-demanding wastewater constituents, organic and inorganic settleable solids, suspended solids, floatable materials, toxic metals or substances, nuisance-stimulating nutrients, and waste heat. Common water treatment technologies include coagulation, primary settling, secondary settling, trickling filter, activated sludge, digestion, ponds or lagoons, pH adjustment, sand filtration, chlorination, and flotation.

Effluent treatment frequently results in the concentration of restricted materials that have no commercial value. Many of these liquid wastes are now stored in open pits. Alternatives to open pit storage include underground injection, immobilization, ocean disposal, disposal by dilution during flood periods, and incineration of organic materials. In the United States, underground injection of hazardous and non-hazardous liquid wastes is a preferred technology.

The ability of certain geologic structures to trap liquids for geologic time is implied by the existence of oil and gas deposits. The best management technique for large volumes of produced water from oil and gas wells is reinjection into the subsurface, well below the lowermost protected aquifer. Underground injection can be a safe, economical waste management technique if designed and operated properly.

In Argentina, the common use of underground injection technology should depend on implementation of strict controls and clear demonstrations that injected wastes will not interfere with present or potential use of subsurface water supplies, contaminate interconnected surface waters, or otherwise harm the environment or endanger human health. The best available techniques, equipment and design criteria should be used for subsurface injection systems. Adequate and continuous monitoring of the injection operation is very important. Provision for appropriate plugging of the injection well should be required.

Underground injection is the most economical method for responsible disposal of liquid wastes that are not easily treated on the surface. Operating costs are lower for pretreatment and subsurface disposal than for surface treatment systems. Plant area requirements are very small. Chemical treatment is minimal and filtration is usually the only physical treatment required for underground injection.

SELECTION OF UNDERGROUND INJECTION TECHNOLOGY

The decision to utilize underground injection as a liquid waste management technology is usually based on a feasibility study. Feasibility studies consider the following:

Effluent Properties

Effluent Volume

Hydrologic Setting

Geologic Setting

Geochemical Setting

Cone of Influence

Capital and Operating Costs

Effluent Properties - Waste injection wells are sensitive to effluent with variable chemical compositions to the extent that composition changes create solids or gases. In open systems, atmospheric oxidation may cause precipitation of salts and hydroxides. Aeration equipment is sometimes used to complete the oxidation, followed by settling and filtration. It may be necessary to add flocculent to coagulate suspended solids. Dissolved oxygen from aeration or other effluent constituents may accelerate corrosion. Determination of the injectate corrosivity is necessary for proper equipment and materials selection. Concentrated salt solutions may form crystals in the system. These crystals restrict flow and increase pumping costs. Scale inhibitors, usually phosphates, are injected at the pump manifold to control this problem. Minimum density and maximum viscosity values should be considered when estimating system pressure losses. Compressibility of effluent with a high dissolved gas content should be considered. Gas formation in the subsurface may produce high pressures and a loss of permeability near the wellbore.

Effluent Volume - Injection wells are particularly suited for high volume waste streams. To gain additional capacity and to provide for backup in case of unexpected maintenance, two or three wells within a kilometer of each other may be considered. If flow rates are variable, surge volume in the form of tanks or lined pits should be considered. Restricted entry for humans, livestock and birds should be considered for open pits containing hazardous liquid.

Hydrologic Setting - The depth and extent of the lowermost protected aquifer must be determined. The piezometric surface of the lowermost protected aquifer is used to evaluate the potential effects of injection on abandoned or temporarily abandoned wellbores. It is used to calculate the cone of influence.

Geologic Setting - A suitable injection interval must be determined. The injection interval is the geologic formation into which the effluent is pumped. It must have sufficient porosity, permeability and lateral extent to accept the injectate. For example, if an injection interval is 50 m thick, extends radially 1 km, and has 30% porosity, then it would take 172 years to displace the pore volume with one injection well operating at 750 cubic meters per day. Injection intervals are usually sandstones or vugular limestones. The confining zone is usually clay, marl, bentonite, gypsum, anhydride, and unfractured shale. It restricts the upward movement of waste. Although it is not necessary, it is sometimes preferable to inject into a subsurface structure such as an anticline so that the liquids are more restricted in their movement underground. The possibility of faults or natural fractures should be analyzed with regard to upward fluid movement. Ruble zones of fault planes frequently act as barriers to fluid flow and may result in accumulation of oil and gas. The possible effects of injection on the exploitation of mineral resources should be considered.

Cone of Influence - The cone of influence is the area surrounding the injection well where the pressure increase resulting from injection is greater than the pressure required to drive fluids from the injection interval into the lowermost protected aquifer. Wellbores within the cone of influence may act as conduits for upward fluid movement. In general, wells within 500 m of the injector should contain cement sheaths surrounding the casing through the injection interval and, if abandoned, cement plugs placed above the producing horizon, at the base of the lowermost protected aquifer and at the surface. One should consider the cost effectiveness of recompleting one of these wells to measure directly the effects of injection on overlying aquifers.

Geochemical Setting - Effluent compatibility with in situ minerals and brine in the injection interval and confining zone is preferable. Pumping costs increase if the injectate and formation brine precipitate solids. Costly workovers to ream or acidize the well may be required if the precipitation occurs near the wellbore. Otherwise the well may have to be plugged and abandoned. Dissolution of the formation matrix may create an unstable wellbore. Dissolution of the formation cement may cause a loss of permeability and subsequent increase in pumping costs. Dissolution of the confining zone material may allow increased upward movement of waste.

Capital and Operating Costs - Capital costs for an injection well usually include the purchase of land; engineering and geotechnical studies for government permits; provision of power to the site; drilling, logging, coring, completing and testing the well; and the purchase and installation of surface facilities such as tanks, pipes, pumps and instrumentation. Operating costs include power, monitoring, reporting, chemicals, workovers, and regular maintenance. In general, an injection well can be installed for less than $1.5MM and $250M annual operating budget. This is frequently an order of magnitude less than the cost for a surface water treatment facility.

TYPICAL INJECTION WELL CONSTRUCTION

Non-oilfield injection wells are usually constructed within plant boundaries such that limited space and special safety precautions are necessary. In the oilfield, abandoned producers are frequently recompleted as injectors. All injection wells should have surface casing cemented with centralizers from 50 m below the lowermost protected aquifer to surface. The surface casing should be at least 5 cm smaller than the drilled hole. This procedure protects shallow aquifers from contamination. Unless the data is available elsewhere, run an electric log prior to casing the upper aquifers.

Drilling continues after the surface casing is installed. Total depth depends on the geologic target, but varies between 500 and 2500 meters. Cores should be collected of the confining zone and injection interval. The cores should be analyzed for fractures, porosity, permeability, and effluent compatibility. Radioactive and electric logs should be run in the open hole. A mini-pump test should be considered to confirm surface equipment design criteria. When a suitable injection interval is found, the well should be completed with tubing and packer. A tubing and packer completion is recommended to allow timely detection of tubing and casing leaks. In unconsolidated formations, a gravel pack may be necessary to improve the operation of the well.

Continuous monitoring is an important factor in maintaining the legitimacy of the disposal technique. The most common complaint about underground injection is a doubt that the operator is sure where the effluent is going; after all, no one can see 1000 meters underground. The most direct approach to this concern is a good monitoring, maintenance and testing program. Continuous monitoring includes the following parameters: annulus pressure and effluent injection rate, temperature, and pressure. Monthly measurements of injectate density and viscosity are recommended for inclusion as data in predictive computer models. Annual testing of the annulus-tubing-packer seal is recommended with public disclosure of this information to demonstrate compliance with applicable regulations.

RECOMMENDATIONS

Promulgate laws and regulations which favor the most cost effective, protective waste management solutions. Use of cost effective, protective solutions is good for the environment, business, voters and government. In certain geologic provinces, underground injection is a viable, protective technology requiring minimum disruption of operations and the local environment, with a short implementation schedule and reasonable cost.

Create a government-industry-public forum to identify, prioritize and resolve technical and political issues regarding underground injection. The forum could be useful in establishing standards of construction, testing and monitoring to improve the application of underground injection technology. The scientific literature should be thoroughly reviewed by government specialists with the assistance of industry leaders to determine those conditions in Argentina which are favorable and unfavorable to underground injection.

The successful application of underground injection depends on the geologic conditions at the proposed site. Therefore, approval or disapproval of the technique should be based on the merits of the site.

CONCLUSIONS

Underground injection is a well known, successful technique for disposal of large volumes of hazardous and non-hazardous liquid wastes. Technology exists to safely and efficiently design, construct and operate injection wells. The existence of a suitable injection interval with sufficient porosity, permeability and lateral extent is necessary for a successful injection well. Concerns regarding the technology can be overcome with government and public participation in the injection well approval process.

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