EFFLUENT DISCHARGE USING BOREHOLES AND PONDS

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Contents

Summary

The brine can be discharged by injection wells, ponds or infiltration trenches. Injection wells are designed in the same way as normal water wells. Possible clogging problems have to be taken into consideration. The principles of injection well design are developed. They are illustrated by an example. Maintenance and cost assessments are given.

1. General Conditions

Injection boreholes are constructed in the same manner as normal water wells but the greatest care must be taken because they are much more likely to fail than normal wells. Clogging of screens is the most serious problem in injection well operation. Thus screen opening areas and screen length must be optimal. As a rule, the maximum entrance velocity should be less than 0.015 m/s. Therefore, the screen length or screen opening percentage should be twice that used for the withdrawal of the same volume of water.

Water with high salt content can be injected by means of wells or spread in a pond or infiltration trench in order to infiltrate.

The most important design requirement is to locate and design the well or the pond so that any migration of the effluent to the intake structure (wells or infiltration gallery) is impossible. In case of intake and discharge by wells, since the brine is considerably denser than the saline water at the intake, it is wise to inject the brine at a greater depth than the intake. The difference in density will reduce the mixing ability.

2. Injection Well

Injection tubing forms an important part of the design for recharge wells. The injection tube must terminate below the static water level in bank casing and must be designed so that positive pressure exists along its entire length. Back-pressure valves should be installed to eliminate negative pressure in the injection tube. Another important criterion is that the injection tube should provide for full flow to eliminate the possibility of air entrainment.

In weakly consolidated, stratified sediments, the injection pressure must be controlled so that the formation is not fractured. If fracturing occurs, there is usually a severe loss in hydraulic conductivity because the bedding planes are disturbed. On the other hand, if injection is into massive consolidated rock, formation fracturing may increase the rate of injection. Pressures that will cause fracturing range from a low of 11.3 kPa m^{-1} for poorly consolidated coastal plain sediments, to 27.1 kPa m^{-1} for crystalline rock (Howard 1970). For most recharge wells in unconsolidated sediments, the injection pressure should be controlled carefully so that the positive head does not exceed $0.2 \times h$, where h is the depth from the ground surface to the top of the screen or filter pack.

If water is discharged into an injection well, a cone of recharge will be formed which is similar in shape but the reverse of a cone of depression surrounding a pumping well. Recently, in Canada (Bruno 1995) [1], successful tests of injection at high depths, at more than 500 m, have led to a full injection at depth system being developed. In the Canadian case, injection pressures correspond to the required pressures for rock fracturation. High depth injection ensures that there is no possibility of an interaction between the brine and the upper aquifers and/or the sea water.

The equation describing the cone for various discharges can be derived using the same assumptions applied to a pumping well:

$$Q = \frac{ke\,(H - h)}{0.366\log\left(r/r_o\right)}$$

For a recharge of a well penetrating an unconfined aquifer, the following equation is applicable:

$$Q = \frac{k\,(H^2 - h^2)}{0.733\log\left(r/r_o\right)}$$

By comparing the discharge equations for pumping and recharge wells, it might be anticipated that the recharge capacity would equal the pumping capacity of a well if the recharge cone were the same size as the cone of depression. Field measurements, however, show that recharge rates seldom equal pumping rates. Theoretically, a properly designed recharge well will recharge as much as the pumping capacity, but problems associated with water quality, turbidity, and high water temperatures reduce the recharge rate over relatively short periods.

In an ordinary water well, for example, some fine sediment will be removed continually from the formation, whereas in an injection well, these fines are not removed.

In fact, fine material contained in the injection water will continuously sediment in the formation or filter pack outside the screen. Over time the formation slowly becomes clogged (Johnson 1966, Olsthoorn 1982), reducing the capacity of the aquifer to receive water. Because this phenomenon is inevitable, most injection well designers specify that the screen length be much longer than for a water supply well of equal capacity, assuming the aquifer is thick enough, to lessen maintenance. Even dry sand or gravel zones above the aquifer may be screened if the well is used only for injection purposes.

Plugging of the formation around the screen can be caused not only by sand or encrustants but also by air bubbles entrained in the injected water. When air is entrained with injection water, a serious loss of hydraulic conductivity can be expected because air bubbles can effectively block the outward passage of water by plugging pore spaces within the aquifer.

According to experience gained all over the world, the other main causes of the clogging of injection wells are (1) growth of bacteria in the gravel pack and surrounding formations; and (2) reactions between the effluent on the one hand and on the other hand, the native groundwater and aquifer material present in the formation;

Bacteria are also suspended matter, but their combined volume is extremely small. In brine for instance, 10 bacteria per cm^3, each with a volume of 1.5 μm^3, the suspended-matter content of the recharge water equals 0.015 parts per billion, from which obviously no clogging needs to be feared. Bacteria, however, are living things and multiply rapidly when conditions are favorable. Their growth is exponential and after some time they completely seal the wall of the borehole. The exponential growth presupposes an unlimited food supply. This food, however, is only present in small amounts in the recharge effluent, meaning that after a short time an equilibrium situation arises where the available food is used to maintain the population at a constant number and no further growth occurs. When large amounts of biodegradable matter are present in the injection water, a complete sealing of the well may occur within a few weeks.

Reactions involving the recharge water. Reactions between native groundwater and injected effluent can only occur at the start of the injection process, at the interface between the recharge effluent and the displaced native groundwater. In fine-grained formations, this mixing zone is narrow and no adverse effects need to be feared. In coarse-grained sediments and fissured rock formations, an appreciable amount of mixing may take place, but here the porosity is so large that the permeability reduction is negligible. The most important reaction is related to the mixing of anaerobic groundwater containing ferrous iron with aerobic recharge effluent, producing insoluble ferric oxide hydrates. In any case the phenomenon will be limited in extent, since the difference in density between the brine and the native groundwater significantly reduces the mixing ability.

Reactions between the recharge effluent and the aquifer material mainly concern the swelling and dispersion of clay particles. Since the effluent is saline, the risk of swelling and dispersion of clay particles is high when these are present. The dispersed clay particles are entrained by the flowing water over considerable distances, but at a certain

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