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THE EFFECT OF OIL WELL BRINES ON AGRICULTURAL FIELDS AND WATER

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What is Brine and Where Does it Come From?

Brine is the salty water trapped in rock formations associated with oil and gas deposits. It consists mostly of sodium chloride but can also contain other things such as organics, bromide, some heavy metals and boron. Its source as a pollutant is usually oil stripper wells which produce less than 10 barrels of oil per day with typically a 10:1 ratio of brine to oil. Such wells are distributed throughout Kentucky and are often located on farmland. In some cases, brine rises to the land surface even where no oil wells are present.

Why is Brine a Concern?

After separation from the oil, brine is stored in holding ponds near the well. Currently, for technical and economical reasons, disposal of brine from these ponds is likely to cause problems. Releasing brine to the soil-water environment in hopes that dilution will minimize the problem is highly questionable because of its toxicity potential. The main reasons for this are explained below:

High Sodium. Sodium concentration in brine is greater than 1000 mg/L (mg/L=ppm) and varies widely among wells. Sodium concentrations greater than 69 mg/L in water can be toxic to crops. Sodium toxicity is closely related to the level of calcium (Ca) in the water or in the soil. Water or soil into which brine has been discharged should have an EC of less than 2 mmhos/cm and the proportion of dissolved sodium to calcium should not exceed 50% of the calcium concentration, expressed as mg/L. If water of high sodium content is applied to a soil, it moves soil calcium to a greater depth. When calcium concentration is low in the root zone, sodium can be toxic even at concentrations approaching zero. Research in Kentucky showed that about 700 lbs of exchangeable sodium per acre would be toxic in many Kentucky soils. This suggests that Kentucky soils should not be used to dispose of brines because their critical sodium load threshold is very low.

High Chloride. Chloride concentration in brine is also greater than 1000 mg/L and varies widely among wells. It can be toxic to crops at concentrations greater than 106 mg/L in water. Chloride is also toxic to crops at elevated concentrations due to the salting out effect (osmotic pressure). This salting out effect appears to become important at electrical conductivity (EC) levels greater than 2 mmhos/cm. One mmho/cm is equal to approximately 640 mg/L dissolved solids or 350 mg/L chloride. Drinking water has an EC value substantially below 1 mmho/cm. Since salting out effects are generally independent of salt type, they can be caused by either sodium chloride or calcium chloride.

Content of Heavy Metals. Heavy metal content of brines is usually very low. However, iron content can sometimes be quite high (10 to 100 mg/L) even though it quickly oxidizes and precipitates out due to the high pH of the brine.

Content of Boron. Concentration of boron in brines can vary from 10 to 100 mg/L. It is toxic to some crops in soil solution concentrations as low as 4 mg/L. Because of this, soil levels of boron can be increased to plant toxic levels by disposal of brine on soils.

Degree of Alkalinity. As such, alkalinity does not cause toxicity. However, at concentrations greater than 90 mg/L, alkalinity can dramatically increase the toxicity of sodium by removing calcium from the water as calcium carbonate. If this occurs in an agricultural soil due to brine disposal, the soil-water environment could become highly toxic to crops.

How Much Brine Can Be Put Onto An Agricultural Soil Without Crop Damage?.

Three factors determine how much brine can be disposed of on agricultural soils, provided that the brine does not contain boron. The first is the type of crop grown. Different crops tolerate different levels of salt. For example, some clovers are extremely sensitive to salt while some grasses like tall fescue, are quite tolerant (Table 1). The second factor is the cation exchange capacity (CEC) of the soil. For example, a soil with a CEC of 10 meq/100 grams can tolerate approximately 460 lbs of sodium per acre (10% of CEC) before it reaches the critical toxicity threshold. On the other hand, a soil with a CEC of 20 meq/100 grams can tolerate twice that much or up to 920 lbs of sodium per acre before it reaches its critical toxicity threshold. The third factor is the texture of the soil. A sandy soil can take very little sodium chloride salt before it becomes toxic, but a clay soil can take a great deal more because of its higher CEC and water holding capacity.

How Do You Reclaim A Soil That Has Been Contaminated With Brine?

To reclaim a brine contaminated soil, excess salt must be leached downward until the electrical conductivity of the soil solution becomes lower than the critical threshold of the crop to be grown (Values shown for 0% yield reduction in Table 1). In order to leach the excess salt it is necessary to pond water on the land or wait for the natural rainfall to leach the salt. However, because a lot of water is needed to leach the salt, relying on rainfall alone may take more than a year to complete the leaching process. Furthermore, as the salt in the soil is diluted by rainfall, the soil may seal up and stop water movement through it. To prevent the soil from sealing, it is necessary to supply calcium. This is usually done by incorporating calcium into the soil surface before water is ponded.

One of the most commonly used calcium sources is gypsum. Elemental sulfur (S) is used on calcareous soils since it reacts with calcium carbonate in the soil to produce gypsum. Road deicing salt (calcium chloride) can also be used. Table 2 indicates the quantities of gypsum or sulfur that are needed to reclaim brine contaminated soils.

Large quantities of straw are sometimes incorporated into brine contaminated soil to increase water permeability and leaching potential. Supplying some calcium during straw decomposition may be needed to restore soil fertility.

When salt contaminated land is reclaimed, groundwater contamination potential increases, effective reclamation of the soil requires leaching salt deeper into the ground. Therefore, before leaching salt downward, it is important to determine where it will go. If it reaches the groundwater, care must be taken that when it seeps into streams or lakes, the dilution will be high enough to bring the salt concentration to safe levels.

If a brine high in boron has been applied to a soil, the boron content of the soil solution at saturation should be measured. The critical threshold is around 2 mg/L. Fortunately, boron leaches quite easily from a soil, and if a soil is reclaimed from sodium, the chances are good that the boron concentration would be less than 2 mg/L.

Summary

Brine should not be discharged onto soils unless there is no other feasible alternative. If discharged onto soil, the total amount of sodium should not exceed 700 lbs/A. Determination of potential toxicity in soils and/or waters into which brine has been discharged, should be made by measuring EC, sodium, and calcium. The EC should be less than 2 mmhos/cm and sodium concentration should be less than 50% of that for calcium, expressed as mg/L.

Table 1. Crop sensitivity to salts, based on the saturation extract test.

	Expected yield reduction			
	0%	10%	25%	50%
Crop	Electrical Conductivity (mmhos/cm)			
Tall fescue	3.9	5.8	8.6	13.3
Vetch	3.0	3.9	5.3	7.6
Alfalfa	2.0	3.4	5.4	8.8
Clovers, (alskike, ladino, red),	1.5	2.3	3.6	5.7
Barley	8.0	10.0	13.0	18.0
Wheat	6.0	7.4	9.5	13.0
Soybean	5.0	5.5	6.2	7.5
Corn	1.7	2.5	3.8	5.9

Table 2. Amounts of gypsum and sulfur required to replace indicated amounts of exchangeable sodium.

Meq. of Na per 100 gm of soil	Gypsum ($CaSO_4 \cdot 2H_2O$)	Gypsum ($CaSO_4 \cdot 2H_2O$)	Sulfur (S)	Sulfur (S)
	Tons/acre - foot	Tons/acre - 6 inches	Tons/acre - foot	Tons/acre - 6 inches
1*	1.7	0.9	0.32	0.16
2	3.4	1.7	0.64	0.32
3	5.2	2.6	0.96	0.48
4	6.9	3.4	1.28	0.64
5	8.6	4.3	1.60	0.80
6	10.3	5.2	1.92	0.96
7	12.0	6.0	2.24	1.12
8	13.7	6.9	2.56	1.28
9	15.5	7.7	2.88	1.44
10	17.2	8.6	3.20	1.60

* 1 meq/100 grams equals 460 lbs of Na per acre 6 inches deep.

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