Monitoring salt levels in farmland drainage

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In monitoring wastewater discharges for salts as a measure of salt management, two parameters must be considered: (1) salt concentration of the effluent and (2) total mass emissions of salts.

The question arises: Is it necessary to measure both parameters? The answer depends on the purpose for which monitoring is conducted. If the primary consideration is the environmental impact of the discharge, mass emission (the total weight of pollutant) is the more appropriate parameter. This is because the environmental impact of any discharge depends on the capacity of the environment to assimilate the waste, and the potential for assimilation of the salt discharge without a significant negative impact obviously would depend upon the amount of mass emission.

If the purpose is to develop irrigation management for good crop production, measurement of concentration alone may be adequate. This is because crops respond to the concentration of salt in the soil solution, and management must provide concentrations that will not be harmful to plant growth.

Legislation and regulatory activities to protect water quality have been largely directed to industrial and municipal discharges. Attention is now turning toward agricultural water discharges, however, and it is important to recognize one significant difference. Municipalities and industries generally have a fixed amount of water for discharge. Mass emission can be calculated directly from measurements of the level of concentration, and regulation of the concentration may adequately control mass emissions. In agricultural systems, however, mass emission of salts is not proportional to concentration. In fact, most often it varies in the opposite direction: More pollutant is discharged if concentration is low than is discharged if concentration is high. Controls on agriculture resulting in low concentration may actually increase total mass emission.

The point here is that principles and practices that have worked well for industrial and municipal water discharges may not be equally successful if used for control of pollutants in water draining from agricultural systems.

Farmland monitoring systems

What are the possibilities of monitoring subsurface discharges in agricultural systems? (A "subsurface discharge" is water that leaves the root zone, either by flowing out through an artificial drainage system or by moving down through the soil profile to the water table.) For several years, a U.C., Riverside, research team measured and analyzed drainage discharges from farmland in various parts of California. Experience in this research project gives some indication of the difficulties that would be faced by large-scale systematic monitoring.

First, consider artificial drainage systems. Monitoring of mass emissions requires measurement of both concentration and volume of the effluent. Salt concentration in tile drains is easily determined by measuring the electrical conductivity of the effluent. Measuring volume of the effluent is more difficult. Researchers studying the nitrate-nitrogen concentration in several tile drainage systems were at times unable to measure volume: tile lines emptied into ditches that were difficult or impossible to reach; outlets were submerged under water; water from several systems was combined into one pipe before being released; or flow rates were extremely high.

There are other problems in monitoring tile drains. Both concentration and volume of the effluent generally vary with time and must be measured periodically, with the frequency of sampling depending on the magnitude and frequency of the fluctuations. Then, too, measured results often reflect management procedures adopted many years previously but since changed.

Sampling the unsaturated zone

The other type of subsurface drainage from farmland—effluent that leaves the root zone and percolates through the unsaturated zone to the water table—is even more difficult to monitor. Again, the problem is to record both salt concentration and volume of flow.

There are four methods for measuring salt concentration below the root zone:

- Remove soil samples and measure their salt content.
- Extract soil solution into porous ceramic cups installed in the soil, and remove it for analysis.
- Install salinity sensors—porous ceramic plates with electrodes embedded on each side to measure electrical conductivity of the soil solution within the plate.
- Use the "four-probe" method, developed largely at the U.S. Salinity Laboratory, Riverside. It involves direct measurement of electrical conductivity of the soil itself, which depends not only on salt level of the soil solution but also on soil water content, temperature, and other factors.

There are three basic approaches to calculating volume of flow in the soil at depths below the root zone:

- Measurement of hydraulic conductivity of the soil and hydraulic head gradients from which to calculate rate of flow.
- Calculation of drainage volume by measuring the water applied and subtracting the estimated amount of water removed by evapotranspiration.
- Calculation of drainage volume for a given period by multiplying the leaching fraction (chloride in water/chloride in soil) by the amount of water applied.

Some of the procedures for monitoring water quality are laborious and time consuming, others require that instruments be buried in the ground and remain there. Except for the four-probe method, each method of measuring salinity provides a point value, which means that numerous measurements must be made in the field because of inherent variability. In the case of certain calculated values, the results will be an average for the entire field, with considerable variation possible from point to point. Some values—such as hydraulic conductivity—are likely to be log-normally distributed within a field, and minor variations may lead to significant errors during the process of multiplying salt concentration by flow volume to determine mass emissions.

Procedures are not available that would allow accurate, widespread monitoring of mass emission of salts below the root zone, and it does not seem likely that economically feasible procedures can be developed in the forseeable future.

There is an unquestioned need for water quality management in California, and, of course, there are federal and state water quality requirements. Rather than attempting to monitor subsurface discharges, a more practical approach would appear to be careful management of those above-ground inputs to the land that affect quality of drainage—chiefly, irrigation water and fertilizer.