**Load *vs.* concentration: implications for reaching water quality goals**

Michael Cahn and Tim Hartz

Among the controversies regarding water quality regulation in the Central Coast region are the issues of how to measure agriculture's contribution to water quality problems, and how to document the success of best management practices (BMPs) in improving water quality. Water quality can be measured in two ways - by pollutant concentration, or pollutant load. Concentration is the mass of a pollutant in a defined volume of water (for example, milligrams of nitrate-nitrogen per liter, or PPM). Load is the amount (mass) of a pollutant that is discharged into a water body during a period of time (i.e. tons of sediment per year). Both concentration and load provide information of environmental significance, but each has limitations.

Concentration is a useful parameter to assess water quality because it has biological significance to organisms of concern. A high concentration of nitrogen and phosphorus in surface water spurs the growth of phytoplankton, which lowers dissolved oxygen levels, resulting in harm to fish and other aquatic organisms which need oxygen to survive. In drinking water, nitrate-nitrogen levels above 10 PPM are harmful to the health of humans, especially infants. Water quality regulation on the basis of concentration has long been used for point sources of pollution such as factories and power plants. Since such point sources generally have defined wastewater release points, and utilize industrial processes that result in reasonably constant pollutant concentration in wastewater, monitoring concentration makes good sense. Additionally, since it is relatively simple to measure wastewater volume in discharge pipes, pollutant load can easily be calculated if the concentration is known.

Pollutant loading is also a useful measure of water quality; when evaluating an entire watershed or groundwater basin, one can calculate the load a given pollutant that can be accommodated from various sources (agriculture, industry, water treatment plants, etc.) without the watershed or basin exceeding the water quality standard. This allocation of permissible pollutant load by source is the foundation of the Federal Total Maximum Daily Load (TMDL) process used nationwide to regulate water quality issues arising from non-point sources like agriculture.

Unfortunately, in an agricultural context there are serious limitations to both approaches to water quality assessment. The first issue with using concentration is the continuity between agricultural land and the surrounding watershed. Unlike industrial sites that can confine processing facilities, few boundaries separate agricultural fields from the surrounding watershed. Fields may receive precipitation during storm events and run-off from adjacent land. Water applied by both irrigation and rainfall can freely percolate to ground water supplies, and surface run-off can exit into neighboring land at multiple locations. The lack of boundaries between cropped fields and the surrounding land means that growers have limited means to control discharge from their operations and accurately monitoring discharge from a ranch or farm can be difficult and expensive.

Also, unlike industries that can reengineer processes to meet water quality concentration goals, agriculture has biological limitations that cannot be manipulated to meet water concentration targets. For example, a goal of discharging agricultural water with a concentration of less than 10 PPM nitrate–N, is currently not feasible in the production of leafy green vegetable crops. Nitrogen is the main nutrient that plants use to manufacture proteins, and must be supplied at a rate to match the demand of the crop. A typical lettuce crop accumulates between 100 and 150 lbs of nitrogen per acre in 60 to 70 day period. Crops mainly take up the nitrate form of nitrogen from soil, and the majority of nitrate uptake occurs by the movement of nitrate to the root surface in the transpirational flow. Since lettuce typically transpires approximately 8 inches of water under coastal conditions, the average nitrate-N concentration of that water would have to average as much as 50-60 PPM to supply sufficient N for growth. In irrigated fields it is inevitable that some leaching will occur, and the nitrate concentration in that leachate will typically be similar to what is in the root zone soil water. Consequently, in leafy green fields, leachate discharged to ground water or to surface water by tile drains during the growing season will inevitably average more than 10 PPM nitrate-N.

A further problem in using concentration targets to regulate individual agricultural producers is that the concentration of nutrients, pesticide, or sediment in discharge may vary significantly during a day, week, or month, depending on the constituent of interest, which fields are being irrigated, and which mix of crops are being raised. The concentration of a soluble nutrient in farm run-off could be far above a concentration goal in the morning, but later in the day, the concentration of the same nutrient could be much lower, and meet water quality targets because the grower is irrigating a different set of fields, or using a different well. Unless many repeated measurements of concentration are taken, assessing the water quality impacts of a particular ranch may be difficult, expensive and imprecise. Additionally, the volume of water discharged from an individual farm may vary greatly during a week or even a day, depending on factors such as how many fields are being irrigated, crop stage, composition of crop types, irrigation method, and time of year. This variation in discharge volume limits how effectively concentration data can be extrapolated to assess if an individual farmer is making progress in meeting water quality targets. A ranch having a low volume of discharge with a high concentration of a nutrient, may have less impact on a receiving water body than a ranch having a high discharge volume but a lower concentration of the same nutrient.

Assessing the load of a nutrient or a pesticide discharged during a defined period of time may be a more accurate assessment of an individual producer's contribution to water quality impairments than measuring the concentration of these pollutants. However, measuring load can be problematic because the volume of run-off or percolation must be accurately estimated. For pollutants such as pesticides, the risk to water quality may depend greatly on the amount of run-off leaving the ranch or farm, and a combination of compiling data on field applications and assessing run-off volume may be the most accurate way to estimate water quality impacts. For nitrate, assessing the amount nitrogen fertilizer applied to fields in excess of typical crop N uptake may provide a reasonable estimate of potential environmental loading, since the majority of applied N not taken up by the crop will eventually be lost to the environment.

In summary,

- Concentration is a measure of the amount of a pollutant in a defined volume of water, and load is the amount of a constituent discharged during a defined period of time.
- Concentration data may not accurately assess impacts of individual producers on water quality impairments due to a lack of boundaries between production fields and the surrounding watershed, biological limitations of agricultural production, and variability in volume of run-off and concentration of constituents discharged from agricultural lands.

- Assessing pollutant load would be a more accurate approach to evaluating the contribution of individual producers to regional water quality impairments, but actual measurement of loading can be complicated and expensive. Using an indirect measure of loading such as the rate of inputs applied to production fields, could provide a reasonable estimate of a growers' potential contribution to water quality impairment.