Agriculture in the Midwest and Hypoxia in the Gulf of Mexico

In 1972, oil prospectors found an area in the Gulf of Mexico off the Texas and Louisiana coasts with an unusually low concentration of dissolved oxygen. The phenomenon was believed to be caused by a combination of environmental factors, and with excessively low oxygen levels at or near zero, the water column is unable to support life. Seasonally occurring between April and October the area varies in size each year and has probably always been present. However, marine researchers have found in recent decades that the size of the hypoxic zone has been increasing, and it is generally accepted that what is happening is more than a natural phenomena.

The problem occurs when there is too little dissolved oxygen in the water. At oxygen levels less than 2 - 3 mg/l, the condition is called hypoxic; at zero levels, it becomes anoxic. The condition and its impact on marine life has become a major concern. Researchers indicate that the source of the problem lies in excess nutrients delivered by the Mississippi and Atchafalaya Rivers, in some combination with a naturally occurring phenomenon called stratification and the decomposition of organic matter. Stratification occurs when differences in water temperature caused by spring thaw and summer heat create a saltwater/freshwater boundary near the surface of the gulf water column that cuts off oxygen delivery to the salt water below. It's similar to the way air masses move in our atmosphere.

Nutrient loading affects the level at which algal blooms occur and zooplankton fecal matter is generated and sinks to the lower water column. In particular excessive nitrogen loading causes large amounts of phytoplankton plumes to develop. When these die they sink to the ocean floor and decompose. The bacteria used in the decomposition process consume massive quantities of oxygen, which nearly depletes the oxygen required for other organisms to use. By the time oxygen levels dip below two parts per million, mobile organisms have fled the area and immobile organisms die off.

Excess nutrients also impair rivers within the Mississippi basin. Too much of most crop nutrients may affect fishing, recreation, drinking water supplies, health conditions, and wildlife habitat. In some places excess nutrients even threaten ground-water supplies. Elevated levels of nitrate-nitrogen (nitrate-N) in drinking water supplies are a major concern in the Midwest where much of the drinking water is derived from surface waters.

Hypoxic conditions place a major stress on aquatic life. The Gulf hypoxic zone is in the middle of one of the most important commercial and recreational fishing regions in the U.S. It is the largest hypoxic zone in the U.S. Commercial fisheries have been able to work around the area and while no conclusive economic impacts have been observed there is concern that hypoxia is taking a toll on fish abundance and size, especially shrimp productivity.

Fisheries in other parts of the world have suffered severely from hypoxic conditions. For instance, the Black Sea once supported 26 different species of fish but now only supports 6. Large ecosystems have responded positively to reductions in nutrient loading. The Chesapeake, Tampa, and Sarasota bays have all undergone improvements in water quality with the reduction of nutrients entering these marine systems.

In 2002, the Gulf of Mexico hypoxic zone reached a record 8,500 square miles; roughly the size of New Jersey. The low oxygen zone varies year-to-year depending on timing, stratification, weather patterns, temperature, and precipitation in the gulf. Sediment cores taken from the Gulf by marine scientists indicate there has been significantly less oxygen in those waters in the last fifty years. The flood of 1993 served as strong evidence linking the Mississippi River flows to the size of the Gulf hypoxic zone. That year phytoplankton production reached record levels and the affected area more than doubled.

There has been both concern and debate over how closely hypoxia is linked to agricultural non-point sources, given the fact that there is such a high correlation between Mississippi River basin flows and the size of the hypoxic zone. About 79% of the variation in nitrate-N discharge is linked to the volume of water discharged. However, through the 1990's, studies conducted by the USEPA and US Geological Survey point to commercial fertilizers used in the Upper Mississippi Basin as a major contributor to the Gulf condition. Nitrate is a very common form of nitrogen used in agriculture and research suggests that a large portion of the nitrate-N delivered to the Gulf each year originates as agricultural runoff and atmospheric deposition. Midwest agriculture is highly dependent upon agricultural drainage for efficient crop production, and agricultural subsurface drainage is a major exporter of excess water and nitrate-nitrogen from crop fields to surface waters. The Midwest is in the midst of an environmental and economic situation that it must proactively deal with.

The Mississippi River Basin covers 41% of the contiguous United States. The basin contributes 55% of US agriculture, and 36% of the runoff to the Gulf. Scientists estimate that agricultural production contributes 2.6 lbs of nitrate-nitrogen per acre. Consider that there are 1.2 billion acres involved and it is cause for concern. Many of the sources are traceable, at least to some of the smaller watersheds that make up the Mississippi watershed. About 90% of the nitrate-N discharged via the Mississippi is most likely from agricultural non-point sources, and as much as 56% of this nitrogen may be traced to the portion of the Mississippi basin above the Ohio River, and thus about 34% comes from the Ohio Basin. Also, nitrate contributions are not evenly distributed between watersheds. For instance the Upper Mississippi River Basin accounts for about 15% of the total Mississippi Basin area and 22% of the water discharge, but half of the nitrate discharge.

Since 1980, about 1.6 million tons of nitrogen annually discharges into the Gulf of Mexico. A number of scientists suggest that a 40% reduction in nitrogen loading to the Gulf would be necessary in order to return levels back to what they were between 1950 and 1970. Without continued efforts to reduce nitrogen loading, the problem promises not to go away and continued pressure from development and intensive agriculture are sure to continue.

The source of the problem is somewhat complex, but is becoming clearer. However, how to reduce the nitrate load is the real question. Research has demonstrated a strong linkage between agricultural subsurface drainage and nitrate-N losses to surface waters. Scientists and engineers have formulated a number of potential solutions to help address the problem. One obvious, but least economical, method to reduce nitrate-N losses is to abandon subsurface drainage systems throughout the Midwest. The practicality of this approach is near-zero, however, as crop production would be reduced substantially on millions of acres of productive poorly-drained cropland soils in the Midwest. In addition, sediment and phosphorus concentrations in surface waters would increase.

Other, possibly much more practical methods include:

1) Implement wetland restoration areas, denitrifying ponds or managed riparian zones where drainage water could be “treated” to remove excess nitrate-N, and other potential pollutants before discharge into drainage ditches or streams.

2) Use alternative cropping systems that contain perennial crops to reduce nitrate-N losses.

3) Increase the use improved soil N testing methods to determine the availability of mineralizable N, and N carried over from the previous crop, especially following dry years, legumes, or past manure applications.

4) Fine-tune fertilizer N management - applying the correct rate of N at the optimum time might substantially reduce nitrate-N losses.

5) Improve the management of animal manures lower nitrate-N losses in livestock producing areas. This would include better information on manure nutrient and water contents, and improving application rate uniformity, and incorporating manures in a timely manner.

6) Design new subsurface drainage systems, or retrofit existing drainage systems, to manage soil water and water table levels through controlled drainage, and/or subirrigation, lowering concentrations of nitrate-N in shallow ground water and reducing the discharge of water and nitrate-N to surface waters. This is called Agricultural Drainage Water Management.

As our work moves forward, improved and new solutions will be established as best management practices, which will help Midwest agriculture proactively address the issue of excess nitrate-N in agricultural drainage waters.

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