Implications of Moving to a Phosphorus Based System for Manure Application

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Take Home Messages

1. Nitrogen-based application rates of manure will cause phosphorus to accumulate in soil. Excess phosphorus in soil poses a significant risk to surface water quality.
2. To be sustainable, the agriculture industry must shift to an integrated nutrient management strategy that results in a balance between nutrient inputs and outputs.
3. A shift from nitrogen-based to phosphorus-based application rates of manure will require a much larger land base to accommodate manure.
4. Producers will incur increased costs to transport and spread manure to meet phosphorus-based application rates.

Introduction

Over the past several decades, the livestock feeding industry in Alberta has shifted toward the development of large confined feeding operations in order to maintain profitability. In many regions of the province, these feeding operations can be found in concentrated pockets, resulting in the production of large amounts of manure in relatively small areas.

The most efficient method of utilizing manure is to apply it on agricultural land. This practice has several benefits such as the improvement of soil fertility and soil physical properties, particularly for degraded soils. Mismanagement of manure, on the other hand, can have negative consequences for the environment, through impacting soil, water, and air quality. Excess nutrients that accumulate in the soil are a potential source of contamination for surface and groundwater. The best approach to prevent or reduce the long-term negative impact of manure application on water quality is to base manure application rates on crop nutrient requirements.

In Alberta, through previous codes of practices and now through the regulations in the *Agricultural Operation Practices Act* (AOPA), manure can be land-applied based on nitrogen limits. When manure is applied based on nitrogen requirements of crops however, nutrients such as phosphorus are often applied in excess of crop needs. In light of this, many jurisdictions have or are considering adopting phosphorus-based application rates for livestock manure, or are setting soil phosphorus limits in order to minimize the impacts on surface and groundwater quality.

During 1998 and 1999, attempts were made to develop regulations for the confined feeding livestock industry in Alberta. While nitrogen limits were already defined for Alberta, it was recognized that phosphorus, rather than nitrogen, was the most important nutrient to manage in the soil profile which prompted a request for Alberta Agriculture, Food and Rural Development to develop phosphorus limits for all agriculture lands in the province. Subsequently, the **Soil Phosphorus Limits Project** was initiated in 1999, with the following objectives:

(1) Develop phosphorus limits that will minimize the impacts on water quality for all agricultural lands in Alberta;

(2) Determine the potential economic impacts on the agricultural industry of implementing phosphorus limits;

(3) Identify management options for implementing phosphorus limits; and,

(4) Develop an action plan and time lines for implementation of limits (Paterson et al. 2004).

The Phosphorus Issue

Excess phosphorus in soil is a significant risk to surface water quality. The movement of phosphorus from agricultural land to surface water can lead to accelerated eutrophication (Correll 1998), which is ranked as the most widespread water quality impairment in the United States. Within the agriculture sector, intensive livestock production has been identified as a primary source of phosphorus in surface waters (Sharpley et al. 2003). In Alberta, the Canada-Alberta Environmentally Sustainable Agricultural (CAESA) Agreement water-quality study confirmed that agriculture practices contribute to the degradation of water quality (CAESA 1998).

Extractable phosphorus levels in Alberta soils are generally deficient or marginal for crop production (Manunta et al. 2000), and much of the agricultural land in Alberta can benefit from added phosphorus to obtain optimum crop yield. Over-application of nutrient sources however can greatly increase soil phosphorus levels. Olson et al. (2003) showed that eight years of annual application of manure in southern Alberta increased soil-extractable phosphorus to levels well above those required for optimum crop growth (Figure 1). Since phosphorus tends to remain in the topsoil layer, it is prone to being lost in surface water runoff. Research has clearly shown that as extractable phosphorus levels increase in soil, there is a corresponding increase in concentration of phosphorus in runoff water (Pote et al. 1996).

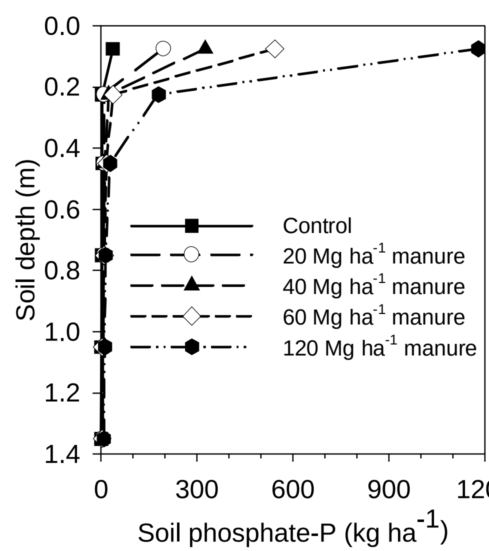

Figure 1. Net cumulation of extractable soil phosphorus in a loam-textured soil near Lethbridge after eight years of cattle manure application (Olson et al. 2003).

The Phosphorus Challenge for Manure Management

It is clear that allowing phosphorus to accumulate in agricultural land poses a significant risk to surface water quality. Using the current AOPA standards, which allow producers to apply manure based on nitrogen limits, phosphorus concentrations in the upper soil profile can quickly increase to levels that pose a risk to surface water quality. To prevent phosphorus from accumulating in soils, changes in manure management must be implemented. One of these necessary changes would be for Alberta to move to manure management based on crop phosphorus requirements. In order to implement such an important change however, it is recognized that there are several issues and challenges associated with a phosphorus-based approach that must first be addressed.

Land-base Requirements

Perhaps the most significant implication of switching from nitrogen- to phosphorus-based manure application rates is the requirement for more land to accommodate manure. For example, the Alberta Fertilizer Guide (Alberta Agriculture 1995) fertilizer recommendations for the major, annual dryland crops ranges from 0 to 110 kg ha^{-1} for nitrogen (N) and 0 to 22 kg ha^{-1} for phosphorus (P). If the mid-way values of 55 kg ha^{-1} nitrogen and 11 kg ha^{-1} phosphorus are used as average fertilizer recommendations, and the nutrient content values for manure in AOPA (Province of Alberta 2001; Schedule 3, Table 5), certain assumptions can be made on manure-nutrient availability to crops. Table 1 shows the calculated nitrogen-based and phosphorus-based application rates. The calculations for this example show that phosphorus-based application rates are about half the nitrogen-based application rates, which means phosphorus-based application of manure would require double the land base. If the phosphorus recommendations are lower, and/or the phosphorus content in the manure is higher, then even more land will be required.

Nutrient Balancing and Crop Rotation Considerations

Phosphorus-based manure application would generally result in under-application of nitrogen relative to crop requirements – a situation that is made worse if manure contains a significant amount of bedding, such as added straw. A large proportion of the crop-available nitrogen can be tied up by the carbon in straw and other bedding materials, or can be immobilized by microorganisms. Producers can improve the situation through minimizing the use of bedding and/or using crop rotations that include legumes in the sequence, both of which may help to balance nutrient levels. It should be noted however, that many other factors should be considered when planning crop rotations.

Manure-application Technologies

The adoption of phosphorus-based management will result in lower manure application rates. When manure is applied in excess of nitrogen requirements, generally there is little concern about how application uniformity will impact crop performance. Current technology does not allow the application of solid feedlot manure to meet only the crop phosphorus needs. Regardless of technology, managing manure as a fertilizer for crop production will require applying lower rates with greater precision and uniformity. In order to meet these specifications, producers will require improved manure application technologies that can handle lower application rates, and that emphasize incorporation or injection of manure to conserve nutrients and minimize contact between manure and surface runoff.

Table 1. Comparing nitrogen-based and phosphorus-based application rates.

	Manure nutrient content[z]					Application rates[y]	
	Total N	NH_4-N	Total P			N-based	P-based
Manure type	kg Mg^{-1}	kg Mg^{-1}	kg Mg^{-1}	Available N^x kg Mg^{-1}	Available P^w kg Mg^{-1}	Mg ha^{-1}	Mg ha^{-1}
Beef (solid)	10	2.6	2.4	4.06	1.68	13.5	6.5
Hog (liquid)	3.5	1.6	1.1	1.84	0.77	30	14.3
Poultry (solid)	29.5	18.2	11.7	18.3	8.19	3	1.3

[z] From AOPA (Province of Alberta 2001); 1 megagram (Mg) = 1000 kilograms (kg) = 1 tonne. The poultry numbers are means of four values.
[y] Based on fertilizer recommendations of 55 kg ha^{-1} nitrogen (N) and 11 kg ha^{-1} phosphorus (P). Manure application rates are on a wet-weight basis.
[x] Assumes 25 percent organic nitrogen (Total N – NH_4-N) becomes available, and 15 percent of the NH_4-N is lost to the atmosphere.
[w] Assumes 70 percent of total phosphorus becomes available.

Livestock Feeding Strategies

Livestock use dietary nutrients with relatively low efficiency. An estimated 40 to 82 percent of nitrogen, 36 to 73 percent of phosphorus, and 75 to 93 percent of potassium fed to livestock is excreted (Barrington 1991). Careful planning of animal rations and feeding practices however, can influence both the amount of manure produced and the nutrient content in the manure. Research has been carried out to improve nutrient-use efficiencies by livestock, and more recently, the environmental implications of nutrient-use efficiency has been assessed. Poulsen (2000) listed four methods to improve phosphorus utilization in hog production: (1) define precise recommendations for rations; (2) improve phosphorus digestibility in feed; (3) select better choice of inorganic phosphorus supplements; and (4) plant breeding. For example, the addition of phytase has been shown to improve phosphorus digestibility in feed for hogs (Poulsen 2000). Many of these methods may apply to other types of livestock. It should be recognized however that the efficiency of nutrient use efficiencies can only be improved to a limited extent, with genetics and biological efficiency of the animals being the major limiting factors.

Manure Processing

As previously indicated, switching to phosphorus-based application rates will result in the need for a larger land base for manure application. This will result in greater transportation costs. Composting raw manure has been suggested as a method to reduce the amount of transportable material (Larney et al. 2000). Composting can greatly reduce the mass and volume of manure. Freeze et al. (1999) reported that the break-even hauling distance for compost is about twice as far as that of fresh manure. During the composting process a significant amount of nitrogen is lost, whereas phosphorus is conserved (Larney 2001). This alters the ratio of nitrogen to phosphorus in compost and as a result worsens the problem of nutrient imbalance relative to crop requirements.

Economic and Policy Frameworks

Applying manure on a larger land base will result in additional time required to handle the manure and increased transportation costs. It is often argued that recommended manure management changes requiring lower application rates to improve environmental sustainability are not economical, due to increased handling and transportation costs. Freeze and Sommerfeldt (1985) concluded it was economically feasible to custom haul manure up to 18 km when the nutrient content of the manure is compared with commercial nitrogen and phosphorus fertilizer costs for southern Alberta. Further to this, Alberta Agriculture, Food and Rural Development is currently engaged in a detailed economic study to assess the costs and benefits associated with various manure management practices.

Soil Phosphorus Limits

Several best management practices (BMPs) have been suggested to control agricultural phosphorus movement from soil into water (Sharpley et al. 2000). In addition to BMPs, soil phosphorus limits or phosphorus indices have been adopted in many jurisdictions (Sharpley et al. 2003). The United States Department of Agriculture Natural Resources Conservation Services instituted national guidelines on nutrient management (Mallarino et al. 2002). The national guidelines suggest the use of one of three phosphorus-risk assessment tools: (1) agronomic soil test phosphorus interpretation classes, (2) environmental soil phosphorus limits, or (3) phosphorus index. In Alberta, a project was initiated in 1999 to develop phosphorus limits for agricultural soils in the province (Olson 2004).

Summary

Environmentally sustainable manure management is an essential component of sustainable livestock production in Alberta. Industry and government collaborated to develop regulations for intensive feeding operations, with land application of manure based on soil nitrogen limits. There is strong evidence however, that with nitrogen-based land application of manure, phosphorus can accumulate in soils and pose a significant risk to water quality.

Moving manure application from a nitrogen- to a phosphorus-based system poses significant challenges, most notably the larger land base that would be required to accommodate the manure in many cases. In areas with concentrations of confined feeding operations this may be particularly challenging, since significant portions of the land base in these areas may already have high soil phosphorus levels. This is compounded by other issues including meeting proper nutrient balances for crops, limitations in manure application technology for applying low rates of manure, manure processing to allow for greater hauling distances, and economic considerations.

Science-based soil phosphorus limits are currently being developed for agricultural soils in Alberta, in order to provide information that will be critical in allowing Alberta to move towards phosphorus based nutrient application.

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