ARKANSAS

Long-Term Effects of Treating Poultry Litter with Alum on Phosphorus Availability in Soils

By P.A. Moore, Jr. and D.R. Edwards

Repeated use of poultry litter as a nutrient source can lead to nutrient imbalances, especially a build-up in extractable phosphorus (P). Addition of aluminum sulfate (alum) to poultry litter has been advocated as a possible means to minimize runoff loss of P from litter when applied to fields. Results from small plot studies showed that P in soils receiving aluminum sulfate–treated (alum-treated) litter was less soluble than P from normal poultry litter, and less P leaching occurred. Larger-scale paired-watershed studies showed significantly less P runoff from fields receiving alum-treated litter compared with normal litter.

Although poultry litter is considered an excellent organic nutrient source, studies have shown that litter applications can result in increased nonpoint source P runoff. When P levels in rivers and lakes are elevated, algal blooms can occur. Some algae produce compounds such as geosmin, which give water a bad taste and smell. In northeast Oklahoma and northwest Arkansas, there are several river systems, such as the Eucha/Spavinaw and Illinois River, which are experiencing water quality problems believed to be linked to excessive P loading (pollution). As a result of high P levels in Lake Eucha and Lake Spavinaw (the drinking water source for the City of Tulsa), eight poultry companies were sued in 2003 by Tulsa for nonpoint source P pollution. Although this case was settled out of court, the state of Oklahoma has recently filed a similar suit with the same companies over litter application in the Illinois River Watershed. The state of Arkansas has petitioned the U.S. Supreme Court to intervene in the case because they believe "states rights" are at stake.

Applying alum in a chicken house.

Most of the poultry farms in the Ozarks region have a sufficient land base to accept the nitrogen (N) associated with the poultry litter generated each year. However, since poultry litter has a low N:P ratio, more P is typically applied than the crops can utilize, when the litter is applied based on its N value. This excess P loading can result in a buildup of soil test P when annual litter applications are made, as well as increased P runoff risk. Most of the P in runoff from pastures fertilized with litter is soluble P, rather than particulate P. Soluble P levels in poultry litter can

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be greatly reduced if the litter is treated with aluminum sulfate (commonly referred to as alum). When the aluminum (Al) in alum binds with the P in litter, P runoff in pastures can be reduced by approximately 75%.

Alum also reduces ammonia emissions from poultry litter. Lower concentrations of ammonia in poultry barns result in a healthier environment for chickens and agricultural workers alike. Bird weight gains, feed conversion, and condemnation rates are improved when alum is used. In addition, energy costs from propane use can be decreased in winter months, since ventilation can be reduced. Reductions in ammonia emissions also result in a higher N content in the litter, which often results in higher crop yields with alum-treated litter. As a result of these benefits, over 700 million broiler chickens are grown each year in barns receiving alum treatment. The USDA Natural Resources Conservation Service (NRCS) provides cost-share support to growers for this best management practice (BMP) in several states. Likewise, many of the poultry companies provide cost-share to growers for using alum, since it improves feed conversion.

While the short-term agricultural and economic benefits of treating poultry litter with alum have been well documented during the past decade, questions often arise as to what the long-term effects of alum are on Al and P availability in soils. Moore and Edwards (2005) showed that alum-treated litter had no effect on Al availability in soils, uptake by plants, and/or in runoff water, whereas additions of ammonium nitrate (NH_4NO_3) fertilizer acidified the soil and resulted in high levels of exchangeable Al and poor forage growth.

The objectives of this study were to evaluate the long-term effects of normal poultry litter, alum-treated litter, and NH_4NO_3 on P availability in soils, P leaching, and P runoff in pastures.

Small Plot Study

A long-term study was initiated in April of 1995 on 52 small runoff plots cropped to tall fescue, located at the Main Agricultural Experiment Station of the University of Arkansas on a Captina silt loam soil (Typic Fragiudult). There were 13 treatments, including four rates of alum-treated poultry litter, four rates of untreated poultry litter, four rates of NH_4NO_3, and one unfertilized control. Litter application rates were 1, 2, 3, and 4 tons/A. Ammonium nitrate application rates were 73, 146, 219, and 292 lb N/A, and were based on the same amount of total N as with alum-treated litter added during year one. There were four replications per treatment in a randomized block design.

Applying litter to paired watersheds.

Soil samples (0 to 2 in.) were taken from each of the 52 plots (10 cores/plot) prior to the study and analyzed for Mehlich 3-P with detection by ICP (Mehlich, 1984) and water soluble P (Self-Davis et al., 2000) The extraction was a 1:7 soil:extraction solution volume ratio. The fertilizer treatments were then randomized, based on Mehlich 3-P values, so the average soil test P level for each treatment was as close as possible (within 1 mg P/kg or 1 part per million [ppm]) to the overall average of 131 mg P/kg.

Soil samples (0 to 2 in.) were also taken periodically (at least one time per year) for the duration of the study and analyzed for Mehlich 3-P and water soluble P. In April, 2002, after 7 years of applications, four soil cores were taken from each plot at the following depths: 0 to 5, 5 to 10, 10 to 20, 20 to 30, 30 to 40, and 40 to 50 cm (0 to 2, 2 to 4, 4 to 8, 8 to 12, 12 to 16, and 16 to 20 in.)

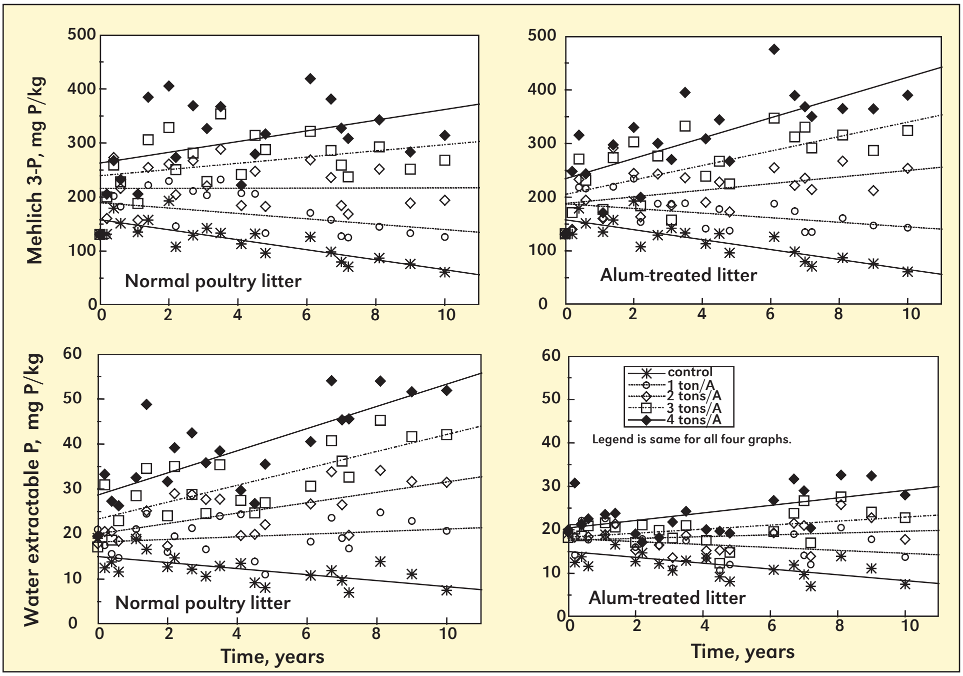

Figure 1. Mehlich 3-P and water soluble P as a function of time for various rates of normal poultry litter and alum-treated litter.

and analyzed for water soluble and Mehlich 3-P.

Trends for Mehlich 3 levels in soil for plots fertilized with alum-treated litter are shown in **Figure 1**. At application rates above 2 tons/A, Mehlich 3-P increased, whereas at rates below this it tended to decrease. These data are similar to Mehlich 3-P values in soils fertilized with normal poultry litter (**Figure 1**).

Water extractable P in soils fertilized with alum-treated litter remained relatively constant or decreased when alum-treated litter was applied at rates of 3 tons/A or less (**Figure 1**). In contrast, water soluble P values increased in soils fertilized with normal litter at rates as low as 2 tons/A (**Figure 1**). In **Figure 2**, the relationship between water soluble and Mehlich 3-P is shown. The slope of the line for normal litter is much steeper than that for alum-treated litter, indicating that for a given Mehlich 3 soil test P level, there will be more soluble P in soils fertilized with normal litter compared to alum-treated litter. This is important, because soluble P is much more subject to runoff and/or leaching reactions than Mehlich 3-P in pastures.

When applied at the same rates, normal poultry litter resulted in roughly three times more soluble P in the surface 0 to 2 in. of soil than alum-treated litter after 7

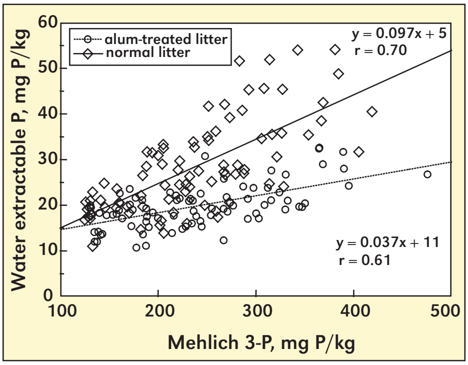

Figure 2. Relationship between water soluble and Mehlich 3 extractable P in soils fertilized with normal or alum-treated poultry litter.

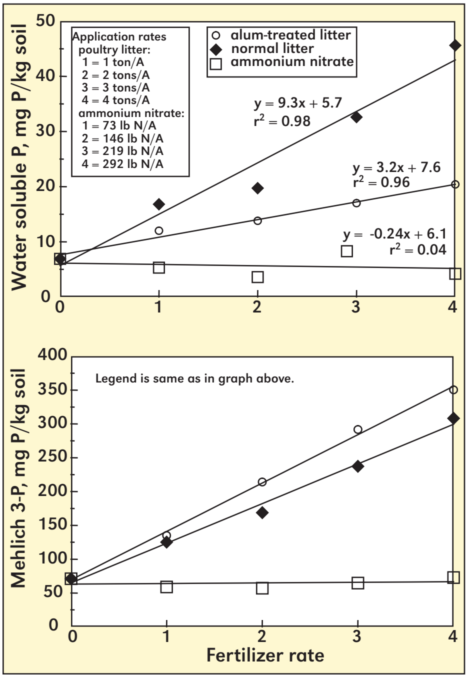

Figure 3. Mehlich 3-P and water soluble P in soil (0 to 2 in.) as a function of fertilizer application rate after 7 years of fertilization.

years of application (**Figure 3**). In contrast, the concentration of Mehlich 3-P was higher for alum-treated litter than normal litter in surface samples taken during year 7.

We hypothesized that elevated Mehlich 3-P in surface soils fertilized with alum-treated litter was related to P solubility (i.e., P from normal litter would leach down the profile because it is more soluble). In order to test this hypothesis, soil samples were taken to a depth of 20 in. during year 7. While Mehlich 3-P was slightly higher in the plots fertilized with alum-treated litter at the surface, it was higher with normal litter at the lower depths, indicating there was much more downward P movement through the profile (leaching) with normal litter than alum-treated litter (**Figure 4**). Further evidence of P leaching with normal litter was provided by the water soluble P levels, which were much higher with normal litter throughout the soil profile. This is the first report of a manure amendment reducing P leaching in soils.

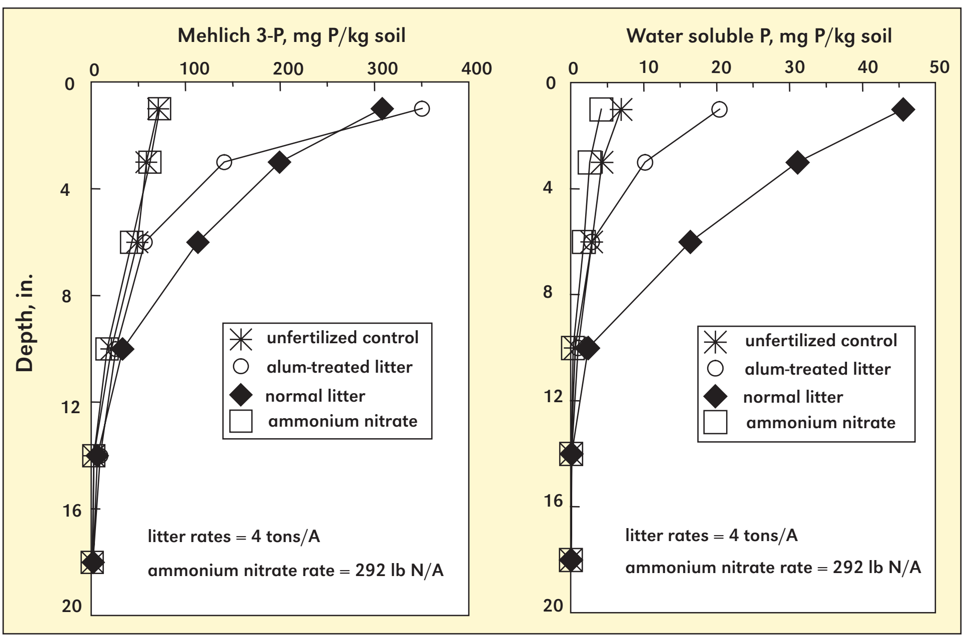

Figure 4. Mehlich 3-P and water soluble P in soil as a function of depth after 7 years of fertilization for the high rates of litter and ammonium nitrate. (Plotted as mean of sampled depth interval.)

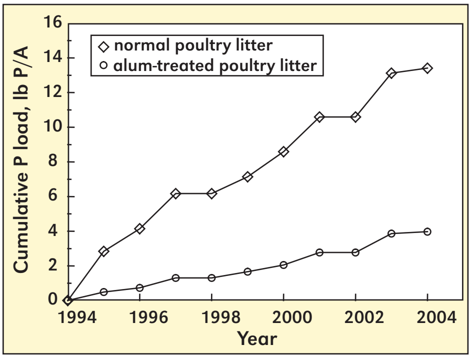

Figure 5. Cumulative soluble P loads in runoff from paired watersheds fertilized with normal and alum-treated poultry litter.

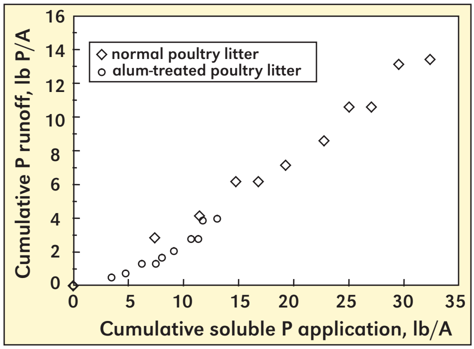

Figure 6. Cumulative P loads in runoff-paired watersheds fertilized with normal and alum-treated poultry litter as a function of cumulative soluble P applied.

Paired Watershed Study

Another long-term (20-year) study was initiated in 1994 using 1-acre paired watersheds located on a commercial broiler/beef farm in northwest Arkansas. The watersheds had earthern berms to hydrologically isolate them from surrounding land and were equipped with runoff flumes and automatic water samplers. Runoff water volumes were measured using pressure transducers connected to data loggers. Samples of runoff water from each event were analyzed for P.

The cumulative P load in runoff from normal litter was 340% higher than that from alum-treated litter (**Figure 5**). Many different studies have shown that P runoff from pastures fertilized with manure is more closely related to the amount of soluble P applied than any other variable. The Mehlich 3 extractable P in both watersheds was almost identical, indicating soil test P had little or no effect on P loading. However, when the cumulative P loads in runoff are plotted as a function of the cumulative soluble P application rate, there is a very good relationship, indicating the amount of soluble P applied is very important in controlling P runoff (**Figure 6**).

Conclusions

The results of this study indicate that the addition of alum to poultry litter is a long-term solution to the P runoff problem. Small plot studies showed P in soils from alum-treated litter was less soluble than P from normal poultry litter. The lower soluble P in alum-treated litter resulted in less P leaching than with normal litter. Likewise, paired watershed studies showed significantly less P runoff from fields fertilized with alum-treated litter. BC

Dr. Moore is with USDA-ARS, located at University of Arkansas, Fayetteville; e-mail: philipm@uark.edu. Dr. Edwards is with the Department of Biological and Agricultural Engineering, University of Kentucky, Lexington.

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