Review of the Application of Polyacrylamides for Soil Erosion Reduction Through Sprinklers

Robert G. Evans
Supervisory Agricultural Engineer
USDA-ARS-Northern Plains Agricultural Research Laboratory
Sidney, MT

Polyacrylamide (PAM) is a generic term applying to an extensive class of organic chemical compounds. There are hundreds of specific PAM formulations with vastly different physical and chemical characteristics with a huge spectrum of uses. For example, cross-linked and super absorbent polyacrylamides are used in contact lenses and baby diapers, whereas certain linear, water-soluble anionic formulations have been successful at reducing soil erosion problems and increasing water infiltration in conventional and surge flow furrow irrigation by stabilizing soil surface structure and pore continuity (Lentz et al., 2001; Trout et al., 1995; Sojka et al., 1998ab). A series of surface irrigation studies (Lentz et al., 1992; Lentz and Sojka, 1994; Mitchell,1986; Trout et al., 1995) have shown that the use of anionic PAM reduced sediment loss by an average of 94% (80-99% range) in field runoff. These results were accompanied by a 15-50% relative infiltration increase compared to untreated controls on medium to fine textured soils, primarily by eliminating or reducing surface sealing (Sojka et al., 1998a). Infiltration rates are often unchanged with sandy soils and may even be slightly reduced by PAM applications due to decreased hydraulic conductivity caused by small viscosity increases in the applied water. Similar, but less sensational results have been observed under sprinkler irrigation.

PAM is economical, typically $4.50 to $12 per kilogram of active ingredient (AI), effective at low rates (1 to 5 kg AI ha^{-1} seasonally), and is relatively easy to use compared to traditional conservation measures. These factors have resulted in rapid acceptance of the technology across the USA an in many countries around the world. It has been estimated by the USDA-NRCS that in1999 about 400,000 ha were treated with PAM in the USA from almost nothing in 1994.

PAM formulations used for erosion control are commercially available in two types of formulations: 1) fine granular (most common), and 2) concentrated liquid emulsions of PAM and mineral spirits and a surfactant to help disperse the PAM when mixed with water. Both granular materials and emulsified concentrates require substantial turbulence or mechanical agitation and high water flow rates at the point of addition to water to adequately dissolve or suspend the PAM material. PAM is sold by a number of commercial companies in a wide variety of active ingredient concentrations.

Application of PAM through Sprinkler Systems

PAM applications with sprinklers has mostly been with self-propelled center pivot systems using emulsion formulations. Documented benefits of PAM under sprinkler irrigation have been more variable and less predictable than under surface systems (Aase et al., 1998; Ben-Hur, 1994; Bjorneberg and Aase, 2000.) It has been shown that sprinkler systems usually need higher seasonal field application totals for similar results because sprinklers must stabilize two to three times more surface area than a furrow irrigated system. In addition, the impact power of water droplets from the individual sprinklers can also result in soil sealing, especially on silty loam soils, which must be countered by even higher PAM application rates (Levin et al., 1991; Smith et al., 1990). Nevertheless, despite the need for higher rates, farmers with center pivot sprinkler infiltration uniformity problems on variable slopes or runoff or run-on problems are finding PAM beneficial in many different situations.

Producers have successfully used PAM with sprinkler irrigation to prevent or reduce runoff/run-on problems, reduce localized in-field ponding, improve stand establishment and enhance irrigation and chemigation uniformity. The movement of soil from raised beds, as used to grow crops such as potatoes, and the associated slumping and degradation of beds is often a serious problem under sprinkler irrigation on many soil types. Several studies have reported improved aggregate stability from sprinkler-applied PAM, leading to decreased runoff and erosion.

The precision of water and chemical applications are improved if infiltration occurs at the point where the applied water hits the soil. This has been a demonstrated benefit to the use of PAM. PAM has also been shown to increase the stability of small tillage reservoirs or pits (e.g., Dammer-Diker ®) which results in longer periods of reduced runoff in center pivot irrigated fields. In addition, applications of anionic polyacrymides through sprinklers have been successfully used to reduce soil crusting effects on emergence of sugar beets and other crops in some cases. It should be noted, however, that conservation practices and reservoir tillage are at least as effective as PAM and tend to last longer. PAM can make these practices better, but should not be viewed as replacement for good farming practices.

PAM applications often allow higher water application rates without runoff. Center pivot and linear move system travel speeds can be reduced to permit greater applied depths per rotation which, in turn, may reduce the amount of time foliage is wetted (less disease), have less evaporation losses and increased efficiencies. Lower machine speeds put less strain on system components which may also lower maintenance expenses. PAM may also allow the use of higher rate sprinklers (if water is available) leading to reduced plugging problems and faster field coverage which may be beneficial for linear move irrigation systems covering large areas.

Many center pivot or linear move fields have widely varying soil types, and only part of the field may benefit from an application of PAM. In these cases, it should be possible to control the injection system with the pivot panel such that the PAM is only applied to that particular part of the field. It may also be advantageous to apply PAM to only the outer 2 or 3 spans, however, it would require a long bypass line mounted on the machine truss to inject the material near the starting point.

Rates. PAM application rates per irrigation of about 1 kg ha^{-1} for furrow irrigation and about 4 kg ha-1 for sprinkler irrigation have been shown to be effective. Additional small applications of PAM may be necessary, if the ground has not been disturbed, on subsequent irrigations to maintain erosion and infiltration benefits. Typical total seasonal applications will vary from 3 to 7 kg ha^{-1}.

PAM is commonly applied through sprinkler systems in 7 to 10 mm (0.3 to 0.4 inches) of water at roughly a 10 g m-3 (10 ppm) concentration in the irrigation water. Multiple applications of PAM through the sprinkler system during the season are generally more effective than a single equivalent high rate application. For soil erosion reduction, it is recommended that PAM be applied in the first irrigation after the last cultivation at about 1 kg/ha (1 lbs AI/ac). An additional 0.5 to 1 kg/ha (0.5 to 1 lbs AI/ac) should also be applied in each of the next 3 irrigations. New applications of PAM will usually be required after tillage operations.

Injection Pumps. Oil-based emusifiable formulations of PAM works well but must applied at fairly low concentrations (e.g., 0.02% AI) and continuously agitated (Bjorneberg, 1998). Progressive cavity pumps are often used for industrial applications. Standard piston-type injections pumps will also pump PAM emulsions, but the material can build up on the check valves in the pump after extended use. Continuous and rigorous agitation by recirculating pumps or mechanical paddles is required. The injection pumps should be flushed with a crop oil before and after injection which removes the emulsion without "activating" the PAM.

Environmental and Safety Concerns. Environmental and safety considerations of anionic PAMs have been reviewed by Barvenik (1994) who concluded that when used at prescribed rates, anionic PAMs are environmentally safe. Negative impacts have not been documented for aquatic macrofauna, edaphic microorganisms, or crop species for the anionic PAM when applied at recommended concentrations and rates for soil erosion reduction (Goodrich et al., 1991; Kay-Shoemake 1998a,b).

REFERENCES

Aase, J.K., D.L. Bjorneberg, and R.E. Sojka. 1998. Sprinkler irrigation runoff and erosion control with polyacrylamide--Laboratory tests. Soil Sci. Soc. Am. J. 62:1681-1687. 1998.

Barvenik, F.W. 1994. Polyacrylamide characteristics related to soil applications. Soil Sci. 158, 235-243.

Ben-Hur, M. 1994. Runoff, erosion, and polymer application in moving-sprinkler irrigation. Soil Science 158(4):283-290.

Bjorneberg, D.L. 1998. Temperature, concentration, and pumping effects on PAM viscosity. Trans. ASAE. 41:1651-1655.

Bjorneberg, D.L., and J.K. Aase. 2000. Multiple polyacrylamide applications for controlling sprinkler irrigation runoff and erosion. Applied Eng. Ag. 16:501-504.

Goodrich, M.S., L.H. Dulak, M.A. Freidman, and J.J. Lech. 1991. Acute and longterm toxicity of water-soluble cationic polymers to rainbow trout (Oncorhynchus mykus) and the modification of toxicity by humic acid. Environ. Toxicol. Chem. 10:509-551.

Kay-Shoemake, J.L., M.E. Watwood, R.D. Lentz, and R.E. Sojka 1998a. Polyacrylamide as an organic nitrogen source for soil microorganisms with potential impact on inorganic soil nitrogen in agricultural soil. Soil Biol. Biochem. 30, 1045-1052.

Kay-Shoemake, J.L., M.E. Watwood, R.E. Sojka., and R.D. Lentz. 1998b. Polyacrylamide as a substrate for microbial amidase. Soil Biol. Biochem. 30, 1647-1654.

Lentz, R.D., and R.E. Sojka. 1994. Field results using polyacrylamide to manage furrow erosion and infiltration. Soil Science 158:274-282.

Lentz, R.D., I. Shainberg, R.E. Sojka, and D.L. Carter. 1992. Preventing irrigation furrow erosion with small applications of polymers. Soil Sci. Soc. Am. J. 56:1926-1932.

Lentz, R.D., R.E. Sojka, C.W. Robbins, D.C. Kincaid, and D.T. Westermann. 2001. Polyacrylamide for surface irrigation to increase nutrient-use efficiency and protect water quality. Commun. Soil Sci. Plant Anal.

Levin, J., M. Ben-Hur, M. Gal, and G.J. Levy. 1991. Rain energy and soil amendments effects on infiltration and erosion of three different soil types. Aust. J. Soil Res. 29:455-465.

Mitchell, A.R. 1986. Polyacrylamide application in irrigation water to increase infiltration. Soil Sci. 141:353-358.

Smith, H.J.C., G.J. Levy, and I. Shainberg. 1990. Water-droplet engergy and soil amendments: Effect on infiltration and erosion. Soil Sci. Soc. Am. J. 54:1084-1087.

Sojka, R.E., R.D. Lentz. T.J. Trout, C.W. Ross, D.L. Bjorneberg, and J.K. Aase. 1998a. Polyacrylamide effects on infiltration in irrigated agriculture. J. Soil Water Conserv. 53:325-331.

Sojka, R.E., D.T. Westermann, and R.D. Lentz. 1998b Water and erosion management with multiple applications of polyacrylamide in furrow irrigation. Soil Sci. Soc. Am. J. 62:1672-1680.

Trout, T.J., R.E. Sojka and R.D. Lentz. 1995. Polyacrylamide effect on furrow erosion and infiltration. Trans ASAE. 38(3):761-765.