LIQUID Animal Manure Application on Drained Cropland: Preferential Flow Issues and Concerns Workshop Summary

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The movement of manure to surface water from artificially drained cropland is a concern. A Liquid Animal Manure Application on Drained Cropland: Preferential Flow Issues and Concerns workshop was held in Columbus, Ohio (November, 2004). The objectives were to: (1) integrate state guidelines into regional guidelines for mitigating liquid manure discharges from artificially drained cropland; (2) identify/prioritize research needs related to the downward movement of animal manure on artificially drained cropland; and 3) identify/prioritize extension and outreach needs related to manure application and pollution of water resources. Recommended regional guidelines for drained fields include monitoring outlets/inlets; matching manure application rates with soil infiltration rates, water-holding capacity of the soil, and crop/soil nutrient needs; and not applying manure when subsurface drains are flowing. Avoid applying manure to flood prone fields, adjust application rates to environmental conditions and ability of the soil to store and utilize manure nutrients (based on nitrogen and phosphorous), and apply manure at a uniform rate and volume to avoid ponding and manure runoff. Future research is needed on pathogen transport and fate; soil preferential flow characteristics; evaluating manure management and equipment application; total manure characteristics (% solids, viscosity, nutrients, pathogens, color); and developing liquid manure testing methods, quick tests, and sensors. Extension activities include developing simple rules for manure application and management; requiring producer certification/education for manure application; developing web based fact sheets, video clips, photographs and demonstrations for preventing manure runoff; promoting partnerships with agencies and animal industry; and educating agency personnell on manure runoff issues.

Keywords: preferential flow, liquid manure, subsurface drainage, macropores, manure runoff

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Subsurface drainage improves crop growth and soil productivity, but can have detrimental environmental effects by increasing the movement of agri-chemicals and nutrients to surface water supplies (Kladivko et al., 2001). Frequently, this increased movement is attributed to preferential flow in soil macropores. Factors such as high intensity rainfall, dry soil, and conservation tillage, because it can contribute to the formation and preservation of soil macropores, increase the potential for preferential flow processes to occur (Shipitalo et al., 2000).

Liquid animal manures are a valuable source of nutrients and organic matter for crop production and can be applied by a variety of methods including spray irrigation, surface spreading, and subsurface injection. Because of their low solids and nutrient content, liquid animal manures are usually applied at relatively high volumes, but it is generally recommended that it not be applied at rates that would exceed the amount needed to bring the soil to field water holding capacity (Johnson and Eckert, 1995). Nevertheless, even when similar guidelines are followed, contamination of drain line effluent has been reported in soils with subsurface drainage due to macropore flow (Geohring et al., 2001).

Application of liquid animal manures to soils with subsurface drainage has been linked to contamination of the effluent with nutrients (Cook and Baker, 2001; Geohring et al., 2001; Stamm et al., 2002), particulate organic matter (Barkle et al., 1999), estrogens (Burnison et al., 2003), bacteria (Bicudo and Goyal, 2003; Cook and Baker, 2001; Dean and Foran, 1992; Jamieson et al., 2002; Joy et al., 1998), and veterinary antibiotics (Kay et al., 2004). These findings are not universal, however, as liquid animal manures can be applied without any detectable adverse effects on water quality. For instance, Randall et al. (2000) noted no difference in nitrogen, phosphorus, or fecal indicator bacteria losses in drainage water when they compared plots that received liquid dairy manure to plots that received equivalent amounts of mineral fertilizer. The fact that liquid animal manures can be safely land applied in some instances, but can cause contamination of subsurface drainage water under different circumstances suggests that the properties of the soil such as soil texture, initial water content, and tillage history as well as the amount of manures applied, application method, water content of manures, and the amount of rainfall after application may all play a role in determining the fate of the applied material.

Materials and Methods

A workshop on Liquid Animal Manure Application on Drained Cropland: Preferential Flow Issues and Concerns was held in Columbus, Ohio on November 9-10, 2004. The objectives of this workshop were: (1) Integrate state guidelines and recommendations for mitigating liquid manure discharges from artificially drained cropland; (2) identify and prioritize extension and outreach needs related to manure application and pollution of water resources; (3) identify and prioritize research needs related to the downward movement of animal manure on artificially drained cropland. Preferential flow and the fate of liquid animal manure on drained cropland presentations were conducted and discussed the first day. The second day, participants divided into three groups and discussed developing regional guidelines, future research needs for preventing preferential flow of liquid manure on drained cropland, and possible extension and outreach programs that need to be conducted. Each participant then used a blue dot (highest priority, 2 points) and a red dot (second priority, 1 point) to score and rank ideas in the research and extension categories. All ideas were recorded and scored, however, similar ideas were grouped together before and after scoring.

Results and Discussions

The content for developing regional guidelines to prevent preferential flow of manure to subsurface drains were identified and discussed. Research and extension activities were also discussed, scored, and ranked.

Regional Guidelines:

Task: Integrate state guidelines and recommendations for mitigating liquid manure discharges from artificially drained cropland to develop regional guidelines. Four major recommendations are:

1) Observation and Monitoring of Tile Inlets and Outlets

Any field where subsurface (tile) drains discharge into ditches that flow to surface water should be considered a high-risk field that is monitored carefully before, during and after a manure application. Apply, observe and monitor tile outlets, evaluate the results, and make adjustments as needed to develop a site-specific manure application plan. Do not apply manure to subsurface (tile) drained fields when the drains/tiles are flowing.

A suggested schedule for observation and monitoring:

a) 10-20 minutes after start of any liquid manure application.

b) Once each 20,000 gallons. Once each hour, if application rate is >20,000 gal/hr. (Example based on Ontario, Canada guidelines.) State and regional rates may vary.

c) Stop application immediately if discharge and/or discoloration observed, implement contingency plan.

2) Liquid Manure Applied to Subsurface Drained Fields

The available water holding capacity of the upper 8 inches of soil (Table 1) provides the approximate volume of water and/or liquid manure that can be applied before water, manure and nutrients begin to move through the soil profile. Manure application rates may need to be adjusted the day manure is applied to avoid reaching and/or exceeding the available holding capacity of the soil. Soils are better able to absorb multiple smaller liquid manure applications than a single large volume application. Field/soil conditions the day of application will dictate the maximum application volume that can be applied. Liquid manure:

a) Should not to be applied on soils that are prone to flooding, as defined by the National Cooperative Soil Survey (or in the Flooding Frequency Soil List posted in Section II eFOTG), during the period when flooding is expected. Manure can be applied if incorporated immediately or injected below the soil surface during periods when flooding is not expected;

b) Application rates should be adjusted to consider the most limiting factor and include the ability of the soil to accept, store and hold liquid manure, water and nutrients and the ability of the plants to utilize these nutrient.

c) Should be applied in a manner that will not result in ponding or runoff to adjacent property, drainage ditches, or surface water regardless of crop nutrient need/requirement;

   Should be uniformly applied at a known rate or volume. Do not apply at rates (volume) that exceed the lesser of the AWC in the upper 8 inches or an effective rate of 13,000 gallons/acre per application (Example based on Ohio guidelines). State and regional rates may vary. The effective rate is used for application equipment with concentrated flows. For example, an injection toolbar with four (4) nozzles on 30 inch spacing. Each nozzle has a concentrated flow over a small area. The effective rate is calculated as the volume of manure applied per area for one (1) nozzle;

d) Prior to manure application, use surface tillage to disrupt the continuity of worm holes, macropores and root channels (preferential pathways) to reduce the risk of manure reaching tile lines, or till the surface of the soil 3-5 inches deep to a condition that will absorb the volume of liquid manure being applied. This is especially important if shallow tile (drains) are present (< 2 feet deep). Any pre-application tillage should leave as much residue as possible on the soil surface to minimize soil erosion;

e) If injection is used, inject only deep enough to cover the manure with soil. Till the soil at least 3 inches below the depth of injection prior to application, or control outflow from all tile outlets prior to manure application;

f) Identify subsurface (tile) outlets, and control or regulate discharge prior to application, or have on-site a means of stopping the discharge from subsurface (tile) drains (e.g. tile plugs, tile stops, or control structures). Use caution not to back-up water where it may impair the functioning of an offsite subsurface drainage system;

g) For perennial crops (hay or pasture), or continuous no-till fields where tillage is not an option, all subsurface (tile) outlets coming from the application area should be identified and flow should be controlled or captured prior to application;

h) Repair broken tile and blowholes prior to application, and follow recommended/required minimum setback requirements (setback distances vary from state to state) for surface inlets;

i) Do not apply manure to subsurface (tile) drained fields when the outlets are flowing;

j) Should a discharge occur, have a plan for dealing with any manure that may reach subsurface (tile) drains, such as blocking outlets or blocking the flow once it reaches the ditch;

k) Avoid applying manure before or after a rain. Keep log of weather forecasts and actual weather conditions 24 hours before and after a manure application with manure application records;

l) Bare/Crusted soils may require some tillage to improve infiltration and absorption. Determine the most limiting application rate base on the field condition and other limitations (may vary from state to state).

<u>These criteria may be waived if the producer can verify there is no prior history of manure discharge via subsurface (tile) drains or discharge is captured. However, if there is a discharge, the producer is liable for damages and is at risk of being classified as a CAFO (Concentrated Animal Feeding Operation).</u>

3) Liquid Manure Applied to Systematic Surface Drained Fields

Fields or areas of fields that have systematic "surface drainage" systems (e.g. shallow surface drains spaced 100 – 200 feet apart – NRCS Surface Drainage-Field Ditch Practice Standard 607) are considered concentrated flow areas. However, if special precautions are taken, manure can be applied in the surface drains with minimal risk of surface runoff. This does not apply to the collector surface drains (mains) or drains bordering the fields. The following special manure application techniques shall be used:

a. Till the surface at least 3 to 5 inches deep prior to <u>liquid</u> manure surface application. Pre-till within 7 days of application.

b. Surface-apply liquid manure <u>uniformly</u> over the entire soil surface on the freshly tilled soil to allow the liquid manure to be absorbed into the soil surface.

c. For fields with no subsurface drainage, liquid manure can be injected directly without prior tillage.

d. Manure application rates should be adjusted to consider the most limiting factor and include the ability of the soil to accept, store and hold liquid manure, water and nutrients. The Nitrogen and Phosphorus Application Criteria for manure, Organic By-Products and Biosolids contained in NRCS Nutrient Management Standard 590 are to be followed to limit transport and leaching..

4) Other Management Criteria

a. Maximize liquid manure storage structures available holding capacity through frequent manure applications under optimal weather conditions. (Do not let manure storage structures get too full.)

b. Size manure application equipment to meet equipment and labor (time) constraints.

c. Calibrate equipment frequently and follow a regular repair/maintenance schedule.

d. Modify crop rotations to fully utilize manure nutrients during the growing season. Plant cover crops after harvest to hold available soil nutrients.

Research Activities:

Task: Identify and prioritize research needs related to liquid animal manure applied to artificially drained cropland. The following topics were listed as priority areas that needed to be researched:

1) Pathogen transport and fate. Score 26
2) Soil types (water holding capacity) and preferable flow characteristics. Score 23
3) Total Manure Characteristics: Particle size, fiber content, percent solids, nutrient content, viscosity, pathogens, color, tied to management systems and research to keep manure out of surface water. Score 17
3) Comparison of existing application methods and application equipment. Compare tillage methods before, during, and after manure application. Score 17
4) Liquid manure testing methods, sensors, quick tests, cost effectiveness. Score 15
5) Correlation of all factors from case file violation cases to identify the magnitude of preferential flow problems. Score 14
5) Research alternative treatment technologies and methods. Score 14
6) Changes in manure, additives to liquid manure, viscosity, value-added, alternative uses. Score 7
6) Precision application technology, mixing, on the go detection and variable rate application. Score 7
6) Socio-economic factors, who pays, adoption of new technology, what combination of educational, technical, financial assistance, and regulation policy is the best. Score 7
7) Water table controls: Compare in soil/in-line storage, site characterization, design, construction, management and duration of control, and management of structures. Score 5
7) Research what happens after liquid manure stored in soil and after it is absorbed. Research what is stored to what is applied to what is discharged. Score 5
8) Research surface water tolerances for manure nutrients, limits, performance standards, and risk assessment. Score 4
9) Alternative storage and handling technology methods. Research storage/handling versus application of manure versus site characteristics. Score 3
9) Portion applied and stored in soil to portion discharged (volume/concentration). Score 3
10) Variability of manure characteristics: species, storage system, and application to fields. Score 2
11) Research the water column and surface applications to the geography setting. Score 1
- What are the most important components to solve problems at a specific operation? No Score
- Systems approach – What is most cost effective for producers? No Score
- Watershed scale studies No Score

Extension Activities:

Task: Identify and prioritize extension, outreach and Technical Service Provider (TSP) needs related to liquid animal manure applied to artificially drained cropland. Seven major extension and outreach issues and educational programs were identified.

1) Keep all information simple and easy to use and integrate simple manure application rules into the whole farm plan. Score 35 points.

Animal manure producers are not utilizing comprehensive nutrient management plans or manure nutrient management plans because they are too complicated and difficult to understand. Need to develop a one-page fact sheet or check list for liquid manure application and one-page record keeping document for animal producers.

2) Required certification and continuing education credits for manure applicators to apply manure. Score 33

Discussion on various state education programs to educate producers about manure management and application. Specific programs mentioned included Livestock Environmental Assurance Programs and a program called Manure Management Issues, Challenges, & Solutions that taught agency personnell how to teach producers about proper liquid manure application techniques; preferential flow issues; winter application of manure; and water quality issues with liquid manure. Suggestions were to develop a notebook for each state on 1) Why liquid manure is a problem; 2) Guidelines on how to apply liquid manure safely, calibrating equipment, and manure application rates; 3) Management of manure storage; 4) State and federal regulations that apply; 5) Risk factors associated with weather, soil moisture conditions, and other environmental factors; and 6) Water quality issues and concerns. Livestock producers tend to apply manure at high rates and have little incentive to apply manure correctly. However, the environmental consequences of pollution from manure for drinking water, fish kills, and wildlife as well as neighbor relations, community perception and public perception may have negative effects on animal production.

3) Develop web based fact sheets, video clips, photos, slides for extension educators. Use demonstrations to educate livestock producers on preferential flow of liquid manure from drained cropland. Score 30

Fact sheets on different types of manure application equipment and how they can be used to apply manure safely. Utilize demonstration projects (e.g. smoking tile lines, monitoring tile outlets) to educate livestock producers on preferential flow issues. Develop workbook with research on applying manure to drained cropland. Recent survey in one state indicated web usage on educational material rated low, short fact sheets rated good, and demonstration and demonstration sites rated high.

4) Promote partnerships with Agencies, Industry, Producers, General Public, and Universities. Promote insurance rate reductions (as high as 30%) for producers who follow MNM plan and EMS procedures, developed by Wisconsin and Michigan. Score 27

Discussed the need to incorporate guidelines for manure application into NRCS technical guide. Need to educate dealers and manufacturers of liquid manure application equipment on how to design equipment that will reduce application rates and preferential flow problems. Agencies and livestock commodity groups should form partnerships and work together to simplify rules. Partnerships need to have a consistent message and should produce educational programs on manure management for livestock producers and grain producers who receive manure. In one program, a state used federal dollars to train consultants to manage manure storage facilities, hire custom manure applicators, develop GPS computer generated setback distances and manure application rates for individual fields, and flag and monitor tile lines for animal operations. Each operation was paid to hire a consultant to apply manure correctly..

5) Train Extension and Agency personnell (EPA, NRCS, SWCD) on Preferential Flow issues related to manure. Score 19

Need to have knowledgeable people at the county level who understand manure issues and who can handle a manure crisis. Need to have people who can deal with cultural differences with large dairies, integrated livestock operations, concerned citizen groups opposed to large operations, and the general public.

6) Develop an Interactive Computer Decision Support Program Model. Score 17

Develop a computer program that inputs 1) field data like soil type, soil moisture, and environmental setbacks, 2) total amount of manure on farm, and 3) climate data and generates output that identifies fields to apply manure and specifies a safe application rate. Could possibly be incorporated into Purdue Manure Nutrient Management Program.

7) Integrate Manure Management for Liquid Manure Application into other programs. Score 13

The issue was developing a comprehensive integrated system for managing and applying manure that addresses all issues. Liquid manure systems have been developed because they are healthier for livestock and manure from these systems is easier to handle, but these systems also generate large volumes of excess polluted water. There is a need to design systems that keep clean water separated from polluted water. Need to design systems that do not impact air quality or water quality. For example, injecting liquid manure may improve air quality by reducing odors but decrease water quality by increasing preferential flow problems. Need consistent recommendations that account for most environmental problems that may occur.

Conclusions

Good management is a key issue in preventing preferential flow of manure to surface water. While weather and some environmental conditions cannot be controlled, producers can control when and how they apply liquid manure. Producers need educational programs and guidelines based upon good research focusing on how to prevent the movement of manure to water resources. This paper outlines the content of recommendations for developing regional guidelines to prevent manure runoff. Future research needs and extension and outreach activities are identified to help producers apply liquid manure in a manner that minimizes the potential for impacting water resources through the downward movement of manure into subsurface (tile) drains. These recommendations incorporate the best available knowledge.

References

Barkle, G.F., T.N. Brown, and D.J. Painter. 1999. Leaching of particulate organic carbon from land-applied dairy farm effluent. Soil Science 164(4):252-263.

Bicudo, J.R., and S.M. Goyal. 2003. Pathogens and manure management systems: A review. Environmental Technology 24(1):115-130.

Burnison, B.K., A. Hartmann, A. Lister, M.R. Servos, T. Ternes, and G. Van Der Kraak. 2003. A toxicity identification evaluation approach to studying estrogenic substances in hog manure and agricultural runoff. Environmental Toxicology and Chemistry 22(10):2243-2250.

Cook, M.J., and J.L. Baker. 2001. Bacteria and nutrient transport to tile lines shortly after application of large volumes of liquid swine manure. Transactions of the American Society of Agricultural Engineers 44(3):495-503.

Dean, D.M., and M.E. Foran. 1992. The effect of farm liquid waste application on tile drainage Journal of Soil and Water Conservation 47(5):368-369.

Geohring, L.D., O.V. McHugh, M.T. Walter, T.S. Steenhuis, M.S. Akhtar, and M.F. Walter. 2001. Phosphorus transport into subsurface drains by macropores after manure applications: Implications for best manure management practices. Soil Science 166(12):896-909.

Jamieson, R.C., R.J. Gordon, K.E. Sharples, G.W. Stratton, and A. Madani. 2002. Movement and persistence of fecal bacteria in agricultural soils and subsurface drainage water: A review. Canadian Biosystems Engineering 44:1.1-1.9.

Johnson, J., and D. Eckert. 1995. Best management practices: Land application of animal manure. The Ohio State University Extension Publication AGF-208-95 (Available online at http://www.ag.ohio state.edu/~ohioline/agf fact/0208.html) (Verified 8 September 2004).

Joy, D.M., H. Lee, C.M. Reaume, H.R. Whiteley, and S. Zelin. 1998. Microbial contamination of subsurface tile drainage water from field applications of liquid manure. Canadian Agricultural Engineering 40(3):153-160.

Kay, P., P.A. Blackwell, and A.B.A. Boxall. 2004. Fate of veterinary antibiotics in a macroporous tile drained clay soil. Environmental Toxicology and Chemistry 23(5):1136-1144.

Kladivko, E.J., L.C. Brown, and J.L. Baker. 2001. Pesticide transport to subsurface drainage tile drains in humid regions of North America. Critical Reviews in Environmental Science and Technology 31:1- 62.

Randall, G.W., T.K. Iragavarapu, and M.A. Schmitt. 2000. Nutrient losses in subsurface drainage water from dairy manure and urea applied for corn. Journal of Environmental Quality 29(4):1244-1252.

Shipitalo, M.J., W.A. Dick, and W.M. Edwards. 2000. Conservation tillage and macropore factors that affect water movement and the fate of chemicals. Soil & Tillage Research 53:167-183.

Stamm C., R. Sermet, J. Leuenberger, H. Wunderli, H. Wydler, H. Fl_hler, and M. Gehre. 2002. Multiple tracing of fast solute transport in a drained grassland soil. Geoderma, 109 (3-4):245-268.

Appendix

Table 1. Available Water Capacity (AWC) Practical Soil Moisture Interpretations for Various Soils Textures and Conditions to Determine Liquid Waste Volume Applications not to exceed AWC.

This table shall be used to determine the AWC (upper 8 inches) at the time of application and the liquid volume in gallons that can be applied not to exceed the AWC. To determine the AWC in the upper 8 inches use a soil probe or similar device to evaluate the soil to a depth of 8 inches.

Available Moisture in the Soil	Sands and Loamy Sands	Sandy Loam and Fine Sandy Loam	Very Fine Sandy Loam, Loam, Silt Loam, Silty Clay Loam, Clay Loam, Sandy Clay Loam	Sandy Clay, Silty Clay, Clay
< 25% Soil Moisture Amount to Reach AWC	Dry, loose and single-grained; flows through fingers. 20,000 gallons/ac	Dry and loose; flows through fingers. 27,000 gallons/ac	Powdery dry; in some places slightly crusted but breaks down easily into powder. 40,000 gallons/ac	Hard, baked and cracked; has loose crumbs on surface in some places. 27,000 gallons/ac
25-50% or Less Soil Moisture Amount to Reach AWC	Appears to be dry; does not form a ball under pressure. 15,000 gallons/ac	Appears to be dry; does not form a ball under pressure. 20,000 gallons/ac	Somewhat crumbly but holds together under pressure. 30,000 gallons/ac	Somewhat pliable; balls under pressure. 20,000 gallons/ac
50 - 75 % Soil Moisture Amount to Reach AWC	Appears to be dry; does not form a ball under pressure. 10,000 gallons/ac	Balls under pressure but seldom holds together. 13,000 gallons/ac	Forms a ball under pressure; somewhat plastic; slicks slightly under pressure. 20,000 gallons/ac	Forms a ball; ribbons out between thumb and forefinger. 13,000 gallons/ac
75% to Field Capacity Amount to Reach AWC	Sticks together slightly; may form a weak ball under pressure. 5,000 gallons/ac	Forms a weak ball that breaks easily, does not stick. 7,000 gallons/ac	Forms ball; very pliable; slicks readily if relatively high in clay. 11,000 gallons/ac	Ribbons out between fingers easily; has a slick feeling. 7,000 gallons/ac
100% Field Capacity	On squeezing, no free water appears on soil, but wet outline of ball on hand.	On squeezing, no free water appears on soil, but wet outline of ball on hand.	On squeezing, no free water appears on soil, but wet outline of ball on hand.	On squeezing, no free water appears on soil, but wet outline of ball on hand.
Above Field Capacity	Free water appears when soil is bounced in hand.	Free water is released with kneading.	Free water can be squeezed out.	Puddles: free water forms on surface