State of Wisconsin
Governor Scott Walker

Department of Agriculture, Trade and Consumer Protection
Ben Brancel, Secretary

August 17, 2011

TO: Members of the Department of Agriculture, Trade and Consumer Protection Board

FROM: Ben Brancel, Secretary

RE: Use of Center Pivots for Spreading Manure on Farm Fields

At a recent Board meeting a request was made for more information on the use of center pivots for spreading manure on farm fields. I asked Mike Murray, Livestock Facility Siting Manager, in the Division of Agricultural Resource Management to evaluate available research and science with respect to the use of center pivots and the spreading of manure. Attached please find the document prepared by Mike. Be assured that DATCP will continue to work with the Department of Health Services and the Department of Natural Resources to evaluate how this technology may fit into livestock farming systems in the future.

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Spray irrigation of manure
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There are different systems used for irrigating liquid manure, each with their own benefits and drawbacks. Irrigating manure liquids can provide greater uniformity in the distribution of manure nutrients, better timing of application to meet crop needs throughout the growing season, the ability to more frequently apply small volumes of manure, and reduced manure tanker traffic and soil compaction during applications. There are disadvantages, such as the potential for increased odors, offsite delivery of airborne pathogens, costs to install and manage fixed systems, and often a negative public perception. The water quality concerns related to nutrient management and spray irrigation are well understood and systems can be designed to address these limitations. Knowledge gaps remain because less research has been quantified the potential public health risks associated with odors, emissions and inhalation of airborne pathogens.

Proper design, installation and operation of an irrigation system are essential for minimizing pollution and public health risks. Different techniques are appropriate to reduce specific risks, and a combination of practices may be necessary:

- Install spray irrigation systems in appropriate locations to minimize surface and groundwater pollution, as well as the potential for offsite impacts such as odors and drift.
- To reduce water quality risks apply manure according to a site specific nutrient management plan that accounts for variations in weather and soil moisture conditions.
- To reduce risks associated with airborne transmission of pathogens, odors and hazardous air pollutants systems should be designed to minimize aerosolization of manure and prior to irrigation the manure should be treated to reduce pathogen concentrations.
- Manure applications made with automated spray equipment should be monitored by competent individuals
- Irrigation equipment must be maintained to deliver consistent applications.

<u>Methods of irrigating manure</u>

Wastewater can be irrigated below ground via distribution pipes or sprayed on the land surface with pressurized equipment. Spray irrigation has been used for both agricultural and municipal/industrial wastewater applications.

Subsurface drip irrigation systems – Subsurface systems uniformly irrigate wastewater to the plant root zone through buried pipes having small orifice emitters. This evaluation excludes subsurface systems because they are generally not used for livestock waste.

Spray irrigation systems

Three common methods used to spray irrigate manure and other wastewater liquids are 1) sprinkler systems, 2) traveling guns, and 3) center pivots. Varying levels of solid separation are necessary to successfully irrigate the liquid portion of the wastewater. For all three systems management is essential to avoid over application of nutrients, odors and offsite drift of contaminates (Pfost, 2001).

Sprinkler systems – A variety of sprinkler designs can be used to irrigate wastewater. Portable systems pump liquids through a flexible hose attached to sprinklers on risers. The sprinklers can be moved throughout the growing season to facilitate nutrient delivery to different locations. Fixed (solid set) systems often employ buried pipes with sprinklers on risers. Despite their ability to provide uniform applications, these systems are rarely used to apply manure because the small nozzle sizes can become clogged with manure solids. Currently the University of Nebraska Lincoln is investigating the use of sprinklers to spray irrigate collected animal lot runoff onto zero discharge vegetated filter strips.

Traveling gun – Manure is pumped through a hose to a wheel cart mounted sprinkler. As wastewater is applied, the sprinkler is propelled through a field towards a portable reel that winds the hose, or the sprinkler is moved on a separate rig. Pulsing travelers work with flexible hose and can use smaller flow rates than traditional traveling guns. Typically, high pressures and sprinklers with large diameter nozzles (> 0.5 inch) are used Some systems can irrigate manure with solids content as high as 8%. Disadvantages are that applications may be uneven throughout a field and the large droplets can damage crops and compact the soil (Jarret, 2008). Because of the high pressures employed significant bioaerosols are generated despite the large droplet size (Boutin, 1988). Spray guns can also be mounted on tractor pulled tankers (as done in the United Kingdom).

Center pivot and linear drive systems – Manure is delivered through a series of sprinkler heads located along elevated distribution pipes. Spray nozzles can be located anywhere from 12 feet above ground to nozzles suspended a few inches above the surface by drop tubes. The units move though the field in two ways 1) in a circular path from a fixed end pivot (center pivot) or 2) laterally moved by drive units attached at each end of the distribution pipe. Both fixed and portable systems can be employed for manure spreading. Fixed systems utilize buried pipes connected to the pivot point and can employ a significant amount of automation, such as high wind shut offs and remote operation. Single pivots can span over 1600 feet. Portable systems have the advantage of being transported to different fields during the growing season; however more labor is required for their set up and operation.

Center pivot irrigation design guidance is quite refined for water delivery, and the principles used to determine spray patterns and application rates seem generally applicable to wastewater. A wide array of sprinkler/spray nozzle configurations and operating pressures can be designed to meet field conditions. The nozzle type and operating pressure are selected for the appropriate spray pattern, some of which can deliver liquid droplets up to 70 feet from the sprinkler head (Kranz 2005). Generally liquid manure having solids content less than 1% can be irrigated through equipment similar to that used for water irrigation. Manure with higher solids content may be irrigated when systems use chopper type pumps and sprayers that irrigate larger droplets; this may require higher pressures for moving the slurry, and the use of end guns.

Water quality considerations

Under the state agricultural performance standards, producers applying nutrients must develop and follow an annual nutrient management plan if required by a municipality or cost sharing is offered. Nutrients include manure, legume nitrogen, organic byproducts and commercial fertilizer. Every field on which a farmer mechanically applies nutrients must have a plan that complies with NRCS Standard 590, Nutrient Management. Under state rules nutrient applications cannot exceed UW crop fertility recommendations, and must meet environmental criteria intended to minimize the risk for producing runoff and leaching to groundwater. The DNR can impose additional nutrient management conditions at operations required to have a CAFO permit under NR 243, e.g. limits on liquid manure spreading during frozen ground conditions. Pathogens have varying survival rates after manure is land applied (Cole, 2000). Reducing runoff and leaching reduces pathogen delivery.

Proper irrigation management is important to avoid adding more nutrients or liquids than crops and soils can handle. Excess application of liquids, or rain shortly after irrigation, can cause nitrogen or other contaminants to leach into groundwater. (Curwen UWEX). Surface runoff may occur when saturated soils receive irrigation liquid. Scheduling wastewater applications during the growing season reduces risks for surface runoff and groundwater leaching because crops can uptake the nutrients (Kranz, 2007). Irrigation equipment can efficiently spray large volumes of wastewater, and poor management or failures associated with automated irrigation equipment have contributed to spills in Ontario and other locations. Programs such as UW's Irrigation Scheduler (WIS) have been developed to balance water application rates with soil moisture levels, evaporation, transpiration, transpiration and leaching. To fine tune application timing automated soil moisture probes can be installed in cropland to relay real time data regarding soil conditions at spray fields.

Public health considerations

Livestock manure contains pathogens, bacteria and other compounds that can transmit diseases to humans or animals. Human health concerns traditionally associated with water quality and nutrient management concern nutrients and pathogens entering surface or groundwater (e.g. nitrates). Poor manure management has contributed to water quality degradation and illness, including fatalities in some cases (Gerba, 2004).

Increasing numbers of animals, feed and manure at livestock production facilities contribute to the potential for offsite delivery of interrelated airborne components of dust, odors, hazardous air pollutants and aerosolized (airborne) microbes. Bioaerosols, odors and emissions are generated at locations where manure is land applied as well as at the animal production facility itself. Airborne particles can be inhaled or deposited and ingested by people e.g. deposited on vegetables later eaten. Therefore it is critical to design irrigation systems that reduce offsite delivery of fecal pathogens. Dust does not appear to be a concern with spray irrigation, therefore dust generated from the animal production areas (e.g. barns, animal lots, feed mixing areas) and fields are not considered in this review.

Odor and emissions

Emissions of odors and hazardous air pollutants are distinct, yet often intertwined concerns. Livestock manure odors are recognized as a contributing factor to reduced quality of life in rural communities. Emissions from livestock farms are a growing concern. Research linking air quality and health impacts tends to focus on farm workers, not nearby neighbors. Land application of manure is potentially the largest emitter of air pollution by livestock operations, yet most siting or health regulations in the U.S. focus on the production facility, not land spreading activities.

The primary emissions associated with livestock operations are hydrogen sulfide (H_2S), ammonia (NH_4), greenhouse gasses, volatile fatty acids, volatile organic compounds (VOC) and particulate matter (PM). Odors are comprised of multiple gasses. Levels of hazardous air pollutants vary significantly between different animal types and production systems. The type of liquid manure handling system determines the potential for gas volatilization and odor production at both the production facility and land application sites (CAST, 2011). Manure odors during irrigation are impacted by the type of manure storage and handling system. Larger structures sustain more bacteria populations that are capable of consuming odor forming compounds in manure (Kranz, 2007). Agitation of manure prior to and during irrigation may also impact odors and emissions.

The amount of odors and emissions emitted during land application differ significantly by the method used. Spray irrigation systems and surface applied liquid manure have high odors and emissions compared to applications that inject or incorporate liquid manure (Pfost, 2001). The NR445 Advisory Group recognized incorporation and injection of manure as best management practices for reducing emissions during land application of manure. Odors during irrigation of manure tend to be more intense, but have a shorter duration, than odors associated with spreading by tankers or other common application equipment. Emissions of H_2S, NH_4 and other gasses increase during irrigation when portions of the waste are volatilized. An Idaho study illustrated a range of odor detection thresholds and emission levels (H_2S and NH_4) from low pressure (<35 psi) center pivot dairy manure irrigation systems. Different nozzle configurations and practices, such as low application heights and spraying during low wind periods (<10 MPH), effectively reduced the odor generated (Sheffield, 2004).

Health risks associated with airborne microbes

The fraction of the manure that becomes aerosolized is an important factor in estimating microbial risk. The process of spray application of wastewater to the land surface creates liquid droplets to which bioaerosols attach. Bioaerosols are particles suspended in the air comprised of viruses, endotoxins, mycotoxins, bacteria, fungi, parasites and other live or dead intact microbes, such as insect parts or grain proteins. Some bioaerosols are smaller than 0.02 microns (μm). Liquid droplets or dry materials transport bioaerosols (Millner, 2009). Bioaerosols can impact human health even if the microbes are not alive.

The potential for offsite deposition of bioaerosols is influenced by the 1) characteristics of the waste being irrigated e.g. treated for pathogens; 2) type, design and operation of irrigation systems; and 3) timing of the application, including weather conditions (Dungan, 2010). Spray irrigation systems deliver wastewater droplets that range from very fine (< 100 µm or 0.1mm) to large (> 1,000 µm or 1 mm). Larger droplets do not disperse as far as smaller droplets. Drift of spray droplets is influenced by weather conditions as well as the irrigation equipment. Droplets smaller than 100 µm can evaporate before hitting the ground, whereas droplets larger than 200 µm tend not to. When droplets evaporate the attached bioaerosols can travel further downwind than the original droplet (Hardy, 2006). Bioaerosol concentrations decrease as the distance from spray sites increases. Different pressures and nozzle configurations can be employed to control the droplet size of irrigated manure.

It is understood that spray application of manures and Class B biosolids generate bioaerosols, yet research on the associated health risks are insufficient (Hutchinson, 2008., Peccia, 2006). In general spray applications of wastewater generate more bioaerosols than liquid applications from tankers with splash plates (Tanner, 2008).

Options to reduce risks associated with wastewater irrigation

A combination of items mentioned earlier in this report and the following actions can be used to reduce the impacts to water quality and public health associated with spray irrigation of manure.

Proper operation and maintenance – The most important factor to reduce the potential for spills, over application of nutrients, drift, odors and other offsite impacts is good management of the irrigation system. Management plans that address water quality, nuisance odors and health risks must be developed and followed by producers. Equipment must be operated according to design parameters, manufacture recommendations and nutrient management objectives. Monitoring automated systems during irrigation operations is essential (P3, 2010). Over time, wear and tear of irrigation equipment warrant periodic calibration e.g. nozzle orifices can change size due to abrasion. Operating at higher than design pressures results in smaller droplets, greater potential for drift and excess wear on nozzles; while operating with lower pressures than intended reduces coverage and application uniformity (Evans, 1997). Farm managers must account for all changes in the waste characteristics that could reduce the effectiveness of the system.

The NRCS Standard 590 Nutrient Management requires that manure application equipment be calibrated to ensure that the appropriate application rates are being achieved. County land conservation departments and producers are aware of the need to calibrate land application equipment such as tankers; however, producers may not recognize that irrigation equipment requires extra care to ensure operation during optimal weather conditions to reduce drift, and that automated components of the system must be monitored during use.

Treatment of wastewater before application – Treating liquid manure prior to irrigation can reduce odors, emissions and public health impacts. The municipal/industrial wastewater industry employs a variety of treatment practices to partially treat Class B Biosolids prior to land application, yet most remain uncommon in agricultural systems. Aerobic and anaerobic treatment, filtration, disinfection of wastewater with chlorine, ozone or ultraviolet light have all been used to reduce pathogen loads (NSFC, 1999). Altering the composition of the manure by feeding selective animal diets and by utilizing technologies such as anaerobic digestion, aeration, and covering manure storage structures have been used to reduce odors and air emissions on farmsteads and during land application of manure (CAST, 2011). These methods and others such as lime treatment are also effective at reducing pathogen loads in animal wastes (Gerba, 2004).

Timing of application – Land spreading odors are greatly reduced when manure is incorporated into the soil, however, this is often not feasible when irrigating manure on growing crops. Timing applications to coincide with appropriate weather conditions can reduce negative impacts such as drift and leaching nutrients. The relative humidity, temperature and levels of solar irradiation not only influence transport of microorganisms offsite, these weather conditions impact the survivability of different organisms found in manure (Dungan, 2010). Spray irrigation during very calm and high wind conditions influences offsite impacts, as does wind direction. Monitoring wind speed and direction must be required, and producers should have plans for shutting off equipment during applications if conditions change.

Simultaneous application of water and manure – Odor reductions and decreased chance of damaging growing crops are benefits of diluting manure with water during irrigation. Systems must be specially designed to irrigate both water and wastewater (Kranz, 2007). Combined center pivot systems are generally more expensive. Mixed systems must have working control systems to prevent manure from entering the water supply e.g. check valves to prevent backflow.

Windbreaks – If properly designed, planted and maintained vegetated windbreaks can reduce offsite drift of spray droplets, odors, and emissions. Windbreaks function by disrupting air flow paths between irrigation equipment and offsite receptors. Windbreaks also provide a visual barrier between neighbors and the irrigation equipment.

Separation distance – It is proven that longer distances between the wetted spray area and neighboring residential dwellings, businesses, parks or other features reduces the chance that bioaerosols, odors and emissions will reach these locations. Research on center pivot irrigation of swine manure cited by Dungan and Millner noted that bioaerosol concentration dropped to background levels at distances ranging from 23 m to 70 m (75-230 ft) from the spray application site. When liquid dairy manure is landspread by tanker trucks the total airborne bacteria and coliform concentrations are 100 to 1000 times more concentrated at the edge of the application location than 50 m downwind. Similar reductions in concentrations of airborne microbes and gasses have been documented downwind from the animal production facilities themselves.

Separation distances are often considered a simple way to reduce a host of offsite impacts such as noise, dust, emissions, light etc. A number of codes require separation distances between land application sites and neighbors. Wisconsin Admin. Code NR 204 requires separation distances between sites receiving applications of domestic sewage and neighboring residences. Distances are determined by the application method: surface application requires 500 ft, while incorporation and injection require 200 ft. Wisconsin Admin. Code NR 214 mandates that industrial wastewater irrigation spray fields are located a minimum of 500 ft from inhabited dwellings. The DNR can impose additional distance requirements based on aesthetics or public health concerns. Under both codes separation distances can be reduced with the consent of affected neighbors. A 300 ft setback between inhabited dwellings and municipal wastewater applications sites is imposed by the Idaho Department of Environmental Quality. The Iowa DNR imposes setbacks between manure irrigation sites (operated by confinement operations >500 animal units) and buildings and public use areas dependant on the type of equipment used: 250 ft, low pressure systems (<25 psi), including those with drop nozzles lower than 9 ft, and 750 ft for high pressure systems (>25 psi). Minimum separation distances are required by ATCP 29 to reduce offsite drift and overspray from chemigation (mixed irrigation water and pesticide application) sites: 100 ft setback from roads and consideration of sensitive nontarget areas (e.g. schools, labor camps, parks, surface waters) within 300 ft of the application area.

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