Model the Effectiveness of Vegetated Filter Strips in Reducing Contaminants in Feedlot Runoff

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Overview

- Background
- Exposure model for beef feedlots
- VFSMOD model for Vegetated Filter Strips (VFS)
- Case study
- Conclusions
- Future Work
Open Feedlots for Beef Cattle

- Open beef feedlots are classified as Animal Feeding Operations (AFO) and feedlots with > 1000 head are classified as Concentrated Animal Feeding Operations (CAFO)
- CAFOs are required to retain all manure flows from the feedlot areas resulting from <= 25-year, 24-hour precipitation event under National Pollutant Discharge Elimination System (NPDES) permit.
- AFO with < 1000 head cattle are not required to control runoff but most feedlots >500 head have some kind of runoff control structure.
- Smaller feedlots < 500 head may discharge to nearby surface waters

Source: www.americancattlemen.com/
Runoff from Open Feedlots

• Runoff from feedlots contains high amount of nutrients found in manure and may contain pharmaceutical chemicals given to beef cattle.
• Regulatory agencies require risk/exposure assessment of pharmaceutical chemicals in runoff especially the ones that are excreted in manure over extended periods of time.
• Pharmaceutical chemicals in runoff released from smaller feedlots with no runoff control in place is the worst-case scenario for exposure assessment and needs to be addressed
• VFS can be used to mitigate chemical exposure especially from feedlots with no runoff control in place.

Source: www.openchannelflow.com/assets/uploads/blog_images/feedlot-runoff-during-rain-b.png
Vegetated Filter Strips (VFS)

- VFS are grassed areas designed to handle runoff flows with appropriate slopes and vegetation.
- Filtration, deposition, infiltration, adsorption, absorption, decomposition and plant uptake.
- Effectiveness of VFS in reducing manure contaminants (nitrogen, phosphorus, ammonia, total solids, chemical oxygen demand, and fecal coliform) has been widely researched.
- VFS have been shown to remove 60-80% (average) of these manure contaminants.

Source: www.arcgis.com/
PRZM Feedlot Model

- WinPRZM modified to include build-up application and scraping options
- Chemical excreted daily in manure is “applied” to manure layer and evenly mixed with remaining chemical from previous time step and then re-applied as evenly mixed on next daily step
- Daily constant rates or varying rates over extended periods of time can be simulated
- User can define scraping events to simulate scraping on the feedlot surface up to user-defined depth
- Erosion process (from APEX model) was modified to simulate erosion from manure surfaces
- Runoff extraction model of PRZM is applicable for manure surfaces. Curve number of 95 used for SCS curve number method
- Top soil layer changed to manure layer by updating OC, FC and WP
Why PRZM model?

- PRZM model is widely accepted and used by regulatory agencies for estimating fate and transport of plant protection chemicals
- USEPA's 30-year weather files for 237 locations across the country
- Can be used to estimate fate and transport of chemicals in groundwater and surface water
- Can be used for field level and watershed scale level assessments
- Can be used with VFSMOD for simulating vegetative buffer strips
- Can be used with USEPA waterbodies or other waterbody models like RivWQ, SWAT, etc.
VFSMOD: Vegetative Filter Strip Modeling System

- **VFSmod** [Muñoz-Carpena, et al., 1993b; 1999, 2004] is a field scale, mechanistic, and storm-based model that describes the overland water flow, particle and contaminant filtration in dense vegetation.
- Successfully field-tested for infiltration, flow, particles, bromide, pesticides, and phosphorus (particulate and dissolved)
- Pesticide trapping efficiency increases in VFS as the VFS width increases

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1[Abu-Zreig, 2001; Fox, et al., 2005; Muñoz-Carpena, et al., 1993b; 1999, Kuo et al., 2009; Sabbagh et al., 2009; Poletika et al., 2009; Perez-Ovilla, 2010; Winchell et al., 2011; Yu et al., 2011, 2012, etc.]
Case Study

Feedlot 1 ha (100 x 100 m) 3 m wide & 9 m wide

Runoff Erosion

Vegetated filter strip (VFS)
Density of <500 Head AFO

Feedlot Cattle
1-500 head/county acre

- <25th centile
- 25-50th centile
- 50-75th centile
- 75-90th centile
- 90-95th centile
- >=95th centile

USDA NASS 2012 (Census of Agriculture)
30-yr Normal Annual Precipitation (1981-2010)
Comparisons will be shown for IA vs. PA and PA vs PA2.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>IA</th>
<th>PA</th>
<th>PA2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Region</td>
<td>NE IA</td>
<td>Western PA</td>
<td>Western PA</td>
</tr>
<tr>
<td>Avg Annual Rainfall (inches)</td>
<td>25.9</td>
<td>40.5</td>
<td>40.5</td>
</tr>
<tr>
<td>VFS Sand (%)</td>
<td>20</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>VFS Clay (%)</td>
<td>27</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Soil and Manure DT50 (days)</td>
<td>60</td>
<td>60</td>
<td>10</td>
</tr>
<tr>
<td>Soil and Manure Koc (mL/g)</td>
<td>800</td>
<td>800</td>
<td>100</td>
</tr>
</tbody>
</table>

1-ha (100x100 m) feedlot was modeled with three scenarios and two buffer sizes: 10-feet (3-m) and 30 feet (9-m) wide and 328-feet (100 m) long along the edge of the feedlot.
Feedlot Inputs and Assumptions

- Two cattle cycles per year were assumed to be on the feedlot
- Scraping after 120 days from start of feedlot cycle
- 0.1 kg/ha chemical excreted per day in manure for 90 days in one feedlot cycle
- Assumed 1-ha feedlot with 250 head/acre (175 ft²/head) stocking density and 4% slope
- Assumed a constant 10-cm manure layer on feedlot surface
- Daily depth of manure excreted = 0.16 cm (estimated using daily manure excreted per head, stocking density and density of fresh manure)
- 30-year PRZM weather file (Sioux City for IA and Harrisburg for PA) run on daily time step
Feedlot Simulation

- Chemical in 10-cm manure layer is calculated on daily time step by adding chemical excreted in manure and subtracting chemical lost in runoff, erosion and degradation.
- 10-cm constant manure layer is assumed but chemical is added daily. Chemical in 0.16-cm manure is removed from system everyday to estimate the remaining daily chemical mass in 10-cm manure layer at end of timestep.
VFSMOD and PRZM

- VFS is modeled along the edge of the field modeled by PRZM.
- VFSMOD uses the event runoff inflow, runoff flux, erosion soil loss, and erosion sediment flux as computed from the PRZM model for the crop/weather scenario as input into the VFS.
- Uses a computed soil moisture for the VFS as input to the model.
- PRZM crop/weather scenario is rerun as a turf scenario by changing the cropping parameters and curve numbers to simulate grass on filter strip.
- IA corn scenario soil and turf crop used for IA scenario.
- PA turf scenario used for PA scenario.
Chemical Flux Comparison

Cumulative Runoff and Erosion Flux from Feedlot

Cumulative Runoff and Erosion Flux for IA

Cumulative Runoff and Erosion Flux for PA

Cumulative Runoff and Erosion Flux for PA2
## Chemical Flux Comparison

30-year Cumulative Runoff + Erosion Flux in Kg

<table>
<thead>
<tr>
<th></th>
<th>IA</th>
<th>PA</th>
<th>PA2</th>
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<tbody>
<tr>
<td>Feedlot</td>
<td>4.99</td>
<td>6.67</td>
<td>2.75</td>
</tr>
<tr>
<td>10 ft VFS</td>
<td>3.12</td>
<td>2.63</td>
<td>1.23</td>
</tr>
<tr>
<td>% reduction</td>
<td>37%</td>
<td>61%</td>
<td>55%</td>
</tr>
<tr>
<td>30 ft VFS</td>
<td>1.91</td>
<td>1.13</td>
<td>0.58</td>
</tr>
<tr>
<td>% reduction</td>
<td>62%</td>
<td>83%</td>
<td>79%</td>
</tr>
</tbody>
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Conclusions

- PRZM feedlot model combined with VFSMOD and a waterbody model can be used to model dissolved and solid-phase residues of excreted constituents such as drugs, parasiticides, hormones, and pathogens.
- Assuming 10 cm constant layer of manure is conservative compared to stockpiles.
- Vegetative filter strips can be used as effective mitigation practice.
- VFSMOD shows over 60% reduction for IA and over 79% reduction for both PA sites with 30-ft wide filter strip.
- Feedlot in western PA resulted in more chemical flux than IA due to higher rainfall.
- E-fate of chemical doesn’t have huge impact on effectiveness of VFS.
- 30-feet VFS is 40-60 % more effective than 10-feet VFS in reducing chemical fluxes.
Future Work

- Literature review for effectiveness of VFS in reducing pharmaceutical chemicals in feedlot runoff
- Validate the PRZM feedlot and VFSMOD models against a research study
- Most small feedlots have a solids settling basin to settle solids before releasing feedlot runoff. Add a basin component to the current model setup using an appropriate model
- Evaluate effect of stocking density, initial conditions before rainfall event, slope of feedlot, settling basin on chemical flux in feedlot runoff
Questions