Effect of Grass Buffer Zone Length in Reducing the Pollution from Land Application Areas

ASSOC. MEMBER ASAE
MEMBER ASAE
MEMBER ASAE

ABSTRACT

A field study was conducted to determine the effect of length of grass buffer zones in reducing pollutant concentration in rainfall runoff from land application areas. Evaluation of pollutant concentrations in runoff at various distances downslope from an area where caged-layer poultry manure was applied regularly indicated that for the conditions of this experiment a buffer area length to waste area length ratio of 1.0 was usually required to reduce concentrations to those measured in runoff from a similar plot receiving no manure. Less buffer area would be needed if concentrations greater than background conditions were acceptable.

INTRODUCTION

Land disposal of animal waste has long been recognized as an economical means of productively using manure constituents and an efficient means of disposing of animal waste. However, the nonpoint source pollution potential of runoff from land application sites can be large with high application rates unless control techniques are adequate. Grass buffer areas located between the area receiving animal waste and the stream reduce the concentration and mass entering the stream during rainfall runoff events. The amount of land area required for a land application system increases as the buffer area size increases. Thus, the cost of a buffer zone can be a major factor in the cost-benefit analysis of land application waste treatment.

The objective of this research was to determine experimentally the effectiveness of several lengths of grass buffer zones in improving the water quality of surface runoff from land application areas.

REVIEW OF LITERATURE

Buffer strips are used to control several different types of pollution. Below land application areas, a buffer strip reduces the nutrient load in runoff. A vegetated filter strip is an effective feedlot control practice for improving the water quality related to feedlot runoff. Vegetated filter strips are also used to control sediment on agricultural lands and to remove pesticides from surface runoff.

Doyle et al. (1977). using 45-m and 7-m waste area lengths on a silt loam soil for a forest and grass buffer zone study, respectively, applied 850 kg N/ha (90 t/ha of dairy manure) and found that a 3.8-m forest buffer length and a 4.0-m grass buffer length were useful in improving the water quality of manure-polluted runoff under the experimental conditions. Thompson (1977) measured the nutrients in winter runoff from three surface conditions on a sandy loam soil. With a 24-m long waste area that received approximately 600 kg N/ha (63 t/ha of dairy manure), he found significant reductions in concentrations with distance downslope for buffer strip lengths of 12.2 and 36.6 m.

Edwards et al. (1971), Dickey et al. (1977), and Swan-son et al. (1975) found that a 500-m heavily grassed waterway, vegetative filters, and a serpentine waterway, respectively, permitted highly polluted initial runoff from barnlots and feedlots to be infiltrated into the soil and diluted by runoff from outside areas. Sievers et al. (1975) found that the combined effects of passing lagoon effluent over a 259-m grass terrace and adding dilution water from cropland reduced the concentration of most of the pollutants. Light (1972) described a grass filtration bed for disposal of milking center waste of which one advantage was removal of nutrients contained in the wastewater.

Many researchers have found that control devices that include vegetated buffer strips reduced or even eliminated sediment and nutrient losses. Stewart et al. (1975) proposed vegetated filter strips since the strips trap sediments near their point or origin, but they admitted that more research is needed regarding their design for optimum trapping efficiency and particle size selectivity. Hayes and Barfield (1977) presented a nonsteady-state model for determining the sediment filtration of an artificial grass filter under various flow rates. To control erosion and to protect the edge of fields that are used as turn rows or travel lanes for farm machinery, the Soil Conservation Service (1975) recommends a field border practice that is a strip of perennial vegetation at the edge of a field. Fitzsimmons et al. (1978) evaluated the effectiveness of sediment removal devices for removing sediment, phosphorus, and other materials from surface return flows from irrigation. Karr and Schlosser (1977) reviewed the literature on the possible use of near-stream vegetation to reduce the transport of sediments and nutrients from terrestrial to aquatic environments.

Asmussen et al. (1977) reported that a 24.4-m grassed waterway was effective in reducing the herbicide load in surface runoff from corn plots approximately 9 m in length treated with 2,4-D. The total loss (on sediment
and in solution) of the applied 2,4-D from the plot in dry and wet conditions was 2.5 and 10.3 percent, respectively. Of the 2,4-D lost from the plots and entering the 24.4-m waterway, approximately 30 percent reached the end of the waterway regardless of antecedent soil moisture.

Among these articles are a number of general recommendations on the use of vegetative buffers and some measurements of water quality. However, more data is needed relating buffer zone length to surface runoff water quality in order to design buffer zones to meet water quality goals, and to evaluate cost effectiveness of buffer zones.

### EXPERIMENTAL DESIGN AND PROCEDURES

The field study consisted of measuring rainfall runoff quantity and pollutant concentrations at various distances downslope from an area where caged-layer poultry wastes were applied regularly. Runoff was collected, sampled, and then redistributed at each sampling distance (Fig. 1). Dimensions of the land application areas and nine terraces and the sampler and drainage system placement for the fall and winter are shown in Fig. 1.

The field study was changed somewhat during the spring to examine intermediate sampling distances. The changes are found in Table 1. Two of the long buffer lengths were changed to shorter lengths by adding two more waste areas.

Rainfall runoff was collected in a gutter at the end of each terrace, passed through a tipping-bucket sampler, and redistributed through a slightly tilted, slotted gutter (Fig. 2); or, after runoff passed the last sampling point in each terrace series, it was routed through a tile system away from the plots. Each terrace was bordered by a ditch. The ditches were 40 cm wide and 25 cm deep. Runoff could not enter the top terrace from upslope or run off the sides of the terraces because of a 25-cm berm.

#### TABLE 1. BUFFER AREA LENGTH/WASTE AREA LENGTH RATIO FOR RUNOFF COLLECTED AT DOWNSLOPE SIDE OF THE VARIOUS TERRACES

<table>
<thead>
<tr>
<th>Terrace</th>
<th>For fall and winter</th>
<th>For spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>2</td>
<td>1.6</td>
<td>1.6</td>
</tr>
<tr>
<td>3</td>
<td>Control</td>
<td>Control</td>
</tr>
<tr>
<td>4</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>5</td>
<td>1.4</td>
<td>0.5</td>
</tr>
<tr>
<td>6</td>
<td>2.6</td>
<td>0.75</td>
</tr>
<tr>
<td>7</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>8</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>9</td>
<td>2.0</td>
<td>2.0</td>
</tr>
</tbody>
</table>
was stored in a side-flail manure spreader for 1 or 2 days
lawn spreader with flow control.

face samples were in the clay textural class. When the
initial seeding, with scattered patches of reed
canarygrass, redtop, and common bermudagrass.

cent, the soil horizons were disturbed at the lower end of
upper 10 cm were in the clay loam textural class. Subsur­

The poultry waste from the alley of a caged-layer house
weather, and schedule of field personnel (Table 2). The
maintain a uniform load of 100 kg/ha total Kjeldahl

Availability of most nutrients for runoff transport decreases with time after waste application. To deter­
mine buffer zone effectiveness during the critical period
soil surface. The objective of the grass and soil analysis
was to determine the application rate of nitrogen to

The results of the grass and soil analysis are complicated by the

TKN/ha was applied and depending on the number of
rainfall events, condition of vegetation, and relative
buildup of soil nitrogen. The amount of waste applied was measured by placing 50-by-

### RESULTS AND DISCUSSION

During the experiment, the goal was to keep the

<table>
<thead>
<tr>
<th>Date</th>
<th>TKN</th>
<th>T-P</th>
<th>COD</th>
<th>Cl</th>
<th>TOC</th>
</tr>
</thead>
<tbody>
<tr>
<td>8-23-77</td>
<td>158</td>
<td>31</td>
<td>1,833</td>
<td>26</td>
<td>194</td>
</tr>
<tr>
<td>9-29-77</td>
<td>78</td>
<td>23</td>
<td>223</td>
<td>11</td>
<td>155</td>
</tr>
<tr>
<td>10-12-77</td>
<td>35</td>
<td>8</td>
<td>384</td>
<td>5</td>
<td>47</td>
</tr>
<tr>
<td>11-2-77</td>
<td>53</td>
<td>12</td>
<td>480</td>
<td>5</td>
<td>112</td>
</tr>
<tr>
<td>11-21-77</td>
<td>31</td>
<td>6</td>
<td>259</td>
<td>4</td>
<td>47</td>
</tr>
<tr>
<td>1-15-77</td>
<td>70</td>
<td>19</td>
<td>691</td>
<td>9</td>
<td>113</td>
</tr>
<tr>
<td>1-5-78</td>
<td>28</td>
<td>9</td>
<td>376</td>
<td>4</td>
<td>36</td>
</tr>
<tr>
<td>1-27-78</td>
<td>69</td>
<td>19</td>
<td>847</td>
<td>7</td>
<td>117</td>
</tr>
<tr>
<td>4-21-78</td>
<td>80</td>
<td>24</td>
<td>1,028</td>
<td>14</td>
<td>140</td>
</tr>
<tr>
<td>5-5-78</td>
<td>60</td>
<td>22</td>
<td>816</td>
<td>14</td>
<td>145</td>
</tr>
<tr>
<td>5-17-78</td>
<td>60</td>
<td>20</td>
<td>741</td>
<td>12</td>
<td>167</td>
</tr>
<tr>
<td>Total</td>
<td>722</td>
<td>197</td>
<td>8,678</td>
<td>111</td>
<td>1,273</td>
</tr>
</tbody>
</table>

### TABLE 2. AMOUNT OF MATERIAL APPLIED TO THE WASTE AREAS AS DETERMINED BY PLATE COLLECTION

around each terrace. Drainage water between terraces
was diverted to nonperforated tile drains.

The soil in the buffer zone site is in the Cecil series, a
common soil in the Piedmont subregion of the Southeast.
Overcash et al. (1976) found that surface samples of the
upper 10 cm were in the clay loam textural class. Subsur­
face samples were in the clay textural class. When the
runoff plots were graded to a uniform slope of 6 to 8 per­
cent, the soil horizons were disturbed at the lower end of
the plots. These disturbances could affect the infiltration
characteristics of the soil.

The plots were seeded with a mixture of reed
canarygrass, redtop, and tall fescue in 1974 (Overcash et al.,
1976). Fescue has become the dominant grass since

The grass sample at each sampling point was taken with a 23-by-23-cm template. There were three sampling
points in each composite sample and two composite
samples per terrace both before and after waste was
applied. The grass and loose organic material (dead vegeta­
tion, etc.) on the soil surface were put in plastic bags and
taken to the laboratory for analysis. The grass was wash­
ed by adding 3 L of deionized water to the plastic bag
and shaking the bag 5 min at approximately 200 excu­
sion/min. This was repeated three times to obtain 9 L of
wash water. Samples were taken by stirring the wash
water and dipping the samples from the center of the
container.

Three random 1.9-cm diameter cores of the upper 2
cm of soil were taken at the three sampling points. A
preliminary experiment revealed that the 2-cm depth was
more effective than a 5-cm depth in detecting nutrient
levels near the soil surface. Several soil samples of the
surface 2 and 5 cm were taken before and after waste was
applied and on the fourth and seventh day after waste
was applied. The concentration of TKN was higher in the
surface 2 cm than in the surface 5 cm. Increasing the
depth of sampling resulted essentially in a constant amount
of waste being mixed with a greater amount of soil. Even
though the 2-cm deep sample was more sensitive to
nutrient additions to the soil surface, small deviations
from the 2-cm sampling depth may also result in large
errors in soil nitrogen measurements. Since depths could
be sampled only to plus or minus 1/2 cm and the anteced­
ten moisture content of the soil affected the soil sam­
ping procedure, it was concluded that soil sampling
could be used only as a check for a relative buildup of soil
TKN.

Below each terrace, a composite runoff volume was ob­
tained by collecting approximately 200 mL from each tip
of the 5-L tipping buckets. For runoff collection, barrels
208 L in volume were partially buried at each sampling
station and a 114-L plastic barrel was placed inside each
large barrel. After each rainfall event, barrels containing
runoff were stirred thoroughly before two composite
samples were taken from the middle of the barrel. Com­
posite samples were taken to the laboratory where they
were refrigerated or frozen until the laboratory analysis
was complete. Pollution parameters measured in water
samples included TKN, total phosphorus (T-P),
chemical oxygen demand (COD), total organic carbon
(TOC), chloride (Cl), ammonium nitrogen (NH

Runoff volumes were determined by recording the
number of bucket tips on a mechanical counter. Runoff
volumes were sometimes difficult to quantify, because
the tipping bucket occasionally malfunctioned. Still,
runoff volumes were recorded on part of the terraces for
most runoff events.

### RESULTS AND DISCUSSION

During the experiment, the goal was to keep the
amount of TKN that could be washed from the grass after each waste application at about 100 kg/ha. Mechanisms, such as waste drying to grass, grass uptake, ammonia volatilization, microbial assimilation, and rainfall reduced nutrient levels between waste applications. The amounts that could be washed from the grass immediately after the waste was applied, expressed as percent of the amount applied, were 77 percent of the TKN, 94 percent of the T-P, 96 percent of the COD, and 100 percent of the TOC and Cl. The lower recovery of TKN is likely due to ammonia volatilization since ammoniacal nitrogen was about 40 percent of TKN in the applied waste.

When grass samples were washed 3 days after waste application the amount of TKN, T-P, TOC and COD washed from the grass was reduced compared to immediately after application, suggesting that time of application in relation to time of rain would be important in controlling the runoff concentration. With additional waste applications during a period without much rain, the grass washing data showed a relative buildup on the vegetation of T-P, TOC, and COD compared to TKN and Cl. Again, ammonia volatilization likely caused most of the reduction in TKN recovery. Chloride was lost from the grass only during rainfall; Cl concentrations remained constant during dry periods and dropped to background levels after even small rainfall events. Since nitrate levels were never detected in the grass washings during the experimental period, nitrification of organic nitrogen on the grass did not occur, or nitrate utilization was equal to nitrate production. Even though aerobic conditions were probably prevalent for the waste on the grass, the microbial populations may not have been favorable for nitrate accumulation. Also, most of the grass samples for washing were taken immediately after waste application or after the grass had been exposed to one or more rain events since application.

Values for the surface soil TKN were variable even though a large number of samples were taken and averaged together. The general trend indicated that a slight buildup of TKN occurred with time (Bingham, 1978).

Generally, runoff concentrations of all pollutants measured were greater for small runoff events than for large events. Reductions could not be shown with buffer distance when small events were analyzed, because concentrations for small events usually varied widely depending on how clean the sampling systems were initially. Therefore, only the large runoff events are presented.

The reduction of runoff concentrations in a vegetative buffer area depends primarily upon infiltration or filtering of pollutants in the buffer area and dilution by rainfall in the buffer area. The amount of pollutant to be removed or diluted in the buffer area depends on the pollutant loading coming from the waste area, and the amount of dilution rainfall required to reduce pollutant concentration to a chosen level depends upon the volume and pollutant concentration of the runoff from the waste area. Amount of pollutant transport and volume of runoff from the waste area normally increase with increasing size of waste area. Pollutant concentrations in runoff from the waste area are likely to be variable and can depend upon several factors such as waste type, waste application rate, rainfall intensity, cropping factors, time since waste application, previous rainfall, etc. In order to consider both size of waste area and size of buffer area, the runoff concentration data was plotted against the ratio of buffer area length to waste area length. However, conclusions drawn from this data should be applied with caution to sites with large waste areas since the only waste area lengths used in this experiment were in the range of 8.7 m to 13 m.

Milligrams of pollutant per liter of runoff is plotted
against the ratio of buffer area length to waste area in Fig. 3 through Fig. 9 for TKN, NO$_3$-N, T-P, COD, TOC, Cl, and the volatile solids/total solids ratio. Generally, the data show that concentration reductions still took place at the 0.5 and 0.75 buffer area length/waste area length ratio for the events measured. However, all parameters usually approached the background area runoff concentration at a buffer area length/waste area length ratio of 1.0. The variation in concentrations from one event to another was affected by the number of days since the last waste application, previous rainfall, and, probably, climatic and seasonal factors. The average concentrations during the experiment at each buffer area length/waste area length ratio are shown in Table 3.

A factor affecting the runoff concentration of TKN, T-P, COD, and TOC was the number of days after waste application. Generally, the longer periods between waste application and rainfall resulted in lower runoff pollu-

<table>
<thead>
<tr>
<th>Date</th>
<th>Rainfall cm</th>
<th>Days after waste applied</th>
<th>No. of previous events</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-26-77</td>
<td>5.46</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>11-06-77</td>
<td>4.47</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>1-08-78</td>
<td>2.56</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>1-14-78</td>
<td>4.32</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>1-17-78</td>
<td>2.08</td>
<td>13</td>
<td>3</td>
</tr>
<tr>
<td>1-19-78</td>
<td>4.42</td>
<td>15</td>
<td>4</td>
</tr>
<tr>
<td>1-25-78</td>
<td>2.78</td>
<td>21</td>
<td>5</td>
</tr>
<tr>
<td>4-26-78</td>
<td>14.00</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>5-06-78</td>
<td>4.34</td>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>

FIG. 5 Effectiveness of the grass buffer zone in removing T-P from rainfall runoff.
nutrients on the soil surface did not increase runoff constituent concentrations (Figs. 3, 5, 6, and 7). This phenomenon was caused principally by the decreasing availability of manure constituents with time. Apparently, the amount of these nutrients on the grass influences runoff concentration of nutrients more than the amount of nutrients on the soil surface, because the buildup of nutrients on the soil surface did not increase runoff concentrations at the end of the experiment compared to the beginning. Probably the most evident trend is the effect of previous rain on runoff concentrations. For example, for each rainfall event from January 8 through 25, 1978, the runoff concentration of TKN, NO₃-N, T-P, TOC, Cl, and the volatile solids/total solids generally decreased.

The average NH₄-N/TKN and O-P/T-P ratios for all the surface area length/waste area length ratios were 0.15 and 0.8 respectively. The NH₄-N/TKN and O-P/T-P ratios were measured for one and four rainfall runoff events respectively. The NH₄-N/TKN ratio ranged from 0.32 to 0.04, decreasing as the buffer area length/waste area length ratio increased. The O-P/T-P ratio ranged from 1.00 to 0.42 and also decreased as the buffer area length/waste area length ratio increased. The average NH₄-N/TKN and O-P/T-P ratios for the control were 0.11 and 0.67 respectively.

Runoff volumes, rainfall volumes, and accumulative infiltration/accumulative rainfall ratio (D) for large runoff events on terraces 1, 4, and 7 are tabulated in Table 4. The average runoff percentages for events on October 26 and November 6, 1977, and on May 8, 1978, for which volumes were measured for all the terraces, were 23, 22, and percent respectively. The variability in runoff for different terraces was greater than expected. This variability would affect total mass transport but did not seem to have much effect on concentration.

**CONCLUSIONS**

Applying poultry waste to land application areas resulted in an increase of the rainfall-runoff pollution potential. TKN, T-P, COD, TOC, NO₃-N, and Cl concentrations and the volatile solids/total solids ratio were measured in the composite runoff sample at various buffer area length/waste area length ratios. Grass buffer

(Continued on page 342)

**TABLE 3. AVERAGE CONCENTRATION OF RUNOFF POLLUTANTS AT EACH BUFFER AREA LENGTH/WASTE AREA LENGTH RATIO**

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Buffer area length/waste area length ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>COD</td>
<td>96.93</td>
</tr>
<tr>
<td>TKN</td>
<td>6.88</td>
</tr>
<tr>
<td>T-P</td>
<td>5.06</td>
</tr>
<tr>
<td>NO₃-N</td>
<td>9.46</td>
</tr>
<tr>
<td>Cl</td>
<td>4.03</td>
</tr>
<tr>
<td>TOC</td>
<td>29</td>
</tr>
<tr>
<td>VS/TS</td>
<td>0.35</td>
</tr>
</tbody>
</table>

*For two events; other averages are for nine events.

**TABLE 4. RUNOFF VOLUME, RAINFALL VOLUME, AND ACCUMULATIVE INFILTRATION/ACCUMULATIVE RAINFALL RATIOS (D) FOR THE LARGE EVENTS**

<table>
<thead>
<tr>
<th>Date</th>
<th>Terrace 1</th>
<th>Terrace 4</th>
<th>Terrace 7</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Runoff</td>
<td>Rainfall</td>
<td>D</td>
</tr>
<tr>
<td>10-26-77</td>
<td>0.57</td>
<td>5.46</td>
<td>0.90</td>
</tr>
<tr>
<td>11-6-77</td>
<td>1.12</td>
<td>4.37</td>
<td>0.74</td>
</tr>
<tr>
<td>1-8-78</td>
<td>2.56</td>
<td>2.27</td>
<td>0.70</td>
</tr>
<tr>
<td>1-14-78</td>
<td>2.32</td>
<td>4.22</td>
<td>0.75</td>
</tr>
<tr>
<td>1-17-78</td>
<td>2.08</td>
<td>2.09</td>
<td>0.75</td>
</tr>
<tr>
<td>1-19-78</td>
<td>4.42</td>
<td>4.42</td>
<td>2.20</td>
</tr>
<tr>
<td>1-25-78</td>
<td>2.78</td>
<td>2.78</td>
<td>2.78</td>
</tr>
<tr>
<td>4-26-78</td>
<td>14.00</td>
<td>—</td>
<td>14.00</td>
</tr>
<tr>
<td>5-8-78</td>
<td>1.45</td>
<td>4.34</td>
<td>0.67</td>
</tr>
</tbody>
</table>

1980—TRANSACTIONS of the ASAE 335
zones reduced the pollutant concentrations in the runoff from land application areas to near that of surrounding area runoff at a 1.0 buffer area length/waste area length ratio on the clay loam soil studied. Less buffer area would be needed if concentrations greater than background conditions were acceptable. Waste area lengths in the range of 8.7 m to 13 m were used in this study and caution should be used when considering application of the results of this study to sites with longer waste area lengths, or when the waste area and buffer area are not similar to each other in vegetative cover, soil surface condition, and hydrologic properties.

References