Evaluation of the Filter Mound Treatment System for the Treatment of Milking Center Wastewater

MSU Account Number RC100021, App. Number 112289

Submitted to

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Method

The Department of Biosystems and Agricultural Engineering, Michigan State University, (MSU) conducted analytical monitoring and consulted on the design, operation, and interpretation of results associated with the Elsie and Bath Michigan Bark Filter Mounds (filter mounds). These mounds served as the basis, in part, for the NRCS Interim Standard 796. This report details analytical results and their interpretation.

Table 1 lists the analytical parameters, methods, and the laboratory that conducted the analyses.

| Parameter | Method | Conducted by | | | | | |
|----------------|-----------------------------------|--|--|--|--|--|--|
| COD | HACH 8000 (EPA Approved) | MSU | | | | | |
| TSS and VSS | HACH 8158 and 8164 (EPA Accepted) | MSU | | | | | |
| Alkalinity | HACH 8221 (USEPA Accepted) | MSU | | | | | |
| Ammonia | HACH 10205 (EPA Accepted) | MSU | | | | | |
| Nitrate | EPA 353.2 | Brookside Laboratories, New Knoxville, OH | | | | | |
| Phosphorus | HACH 8190 (EPA Accepted) | MSU | | | | | |
| Total Coliform | HACH 10029 (EPA Accepted) | MSU | | | | | |
| Iron | Prep EPA 3005; Analyses SM 3120B | Brookside Laboratories, New Knoxville, OH | | | | | |
| Manganese | Prep EPA 3005; Analyses SM 3120B | Brookside Laboratories, New Knoxville, OH | | | | | |
| Arsenic | Prep EPA 3005; Analyses EPA 200.7 | Brookside Laboratories, New Knoxville, OH | | | | | |

Table 1. Analytical Parameter, Methods, and Laboratories

Figure 1 is a diagram of the Elsie site, including the location and description of each sampling location. Figure 2 is a photograph of the mound. The sampling chamber (SC), where all samples except those from the septic tanks were collected, is located in the upper left corner of the picture. A close up of the SC is shown in Figure 3. The only time water from the upstream and downstream trenches was flowing was when the localized groundwater table was high which resulted in the SC being filled with water. Consequently to collect samples, a sump pump was used to evacuate the SC for approximately a day before samples were collected. Sampling at the Bath site was limited to the pumping chamber within the septic tank and the upstream and downstream localized groundwater sampling trenches. A similar procedure as that used at the Elsie site was required.

Results and Discussion

Tables 2 – 4 show the results from the Elsie site. Sample availability due to the absence or small volume of water in the trenches and lysimeters during dry ambient conditions, high water table during wet ambient conditions preventing differentiation of the samples flowing into SC without first pumping the SC, and budget constraints prevented the analyses of all of these parameters for each sampling event. Similarly, Tables 5-7 show the data from the Bath site. Farm management issues prevented extensive sampling at this site.

Because of the scarcity of data statistical analyses is not possible, however, trends are apparent. In regard to COD, the Elsie mound apparently initially leached some carbon however, once established, removal through the mound averaged 50% (Table 2). The 2 feet of soil at the Elsie site did not aid in the removal of COD. The COD level in the localized groundwater sampling trenches at both sites was substantially lower (Tables 2 and 5). TSS and VSS at the Elsie site (Table 2) were substantially reduced through the bark. Alkalinity remained relatively constant through the Mound but was significantly lower in the localized groundwater at both sites (Tables 2 and 5). The pH was examined at the Bath site and it increased slightly through the bed, soil, and into the groundwater (Table 5) although the amount of data is very limited. Total *coliform* at the Elsie site was not present in the septic tank and remained very low through the mound although very little data is available (Table 2). At the Bath site, the quantity of total *coliform* was significant in the septic tank but was about three to four logs lower in the localized groundwater (Table 5).

Excellent ammonia removal resulted in the mound at the Elsie site and low levels were present in the localized water table for both sites (Tables 3 and 6). The nitrate level was very low indicating that after ammonia was oxidized to nitrate the nitrate was then denitrified to nitrogen gas. This indicates that the mound and/or soil under the mound must have had anoxic zones. Influent total phosphorus varied greatly at the Elsie site with good removal from the bark and even further removal by the soil (Table 3). Levels in the localized groundwater were very low at both sites (Tables 3 and 6).

The arsenic level exiting the mound was below detection level or very low at the Elsie site and below detection level in the localized groundwater tables (Tables 4 and 7). Mn and Fe did increase, in some cases significantly, through the mound at the Elsie site and potentially slightly in the localized groundwater although very few data points were available (Table 4). At the Bath site, the level of Fe and Mn in the upstream localized groundwater was already high and actually decreased slightly after the mound (Table 7). For reference, the level of metal in the unused bark at the Elsie site is shown in Table 8.

Cumulatively, the results indicate the Michigan Filter Mound effectively removed carbon, nutrients, and bacteria. However, because of the anoxic conditions within the bed and soil combined with the remaining carbon, it appears that Mn and Fe likely served as the electron acceptors for metal reducing bacteria causing their transport. However, without this anoxic condition, the complete minimization of nitrogen would probably not have occurred.



Figure 1. Elsie Site Plan Including Sampling Locations



Figure 2. Photograph of Elise Mound

Figure 3. Photograph of Sampling Chamber



| Date | | | | с | OD (mg/L |) | | | | | | TSS (| mg/L) | | V | SS (mg | /L) | Alkal | linity (n | ng/L Ca(| CO3) | T (cc | otal Co Ionies | oliform /100 m ⁱ | ∟) |
|--------------|------|------|------|------|----------|-----|----|-----|-----|------|-----|-------|-------|-----|-----|--------|-----|-------|-----------|----------|------|----------|-------------------|--------------------------------|----|
| | ST | ST2 | ST3 | BL | SL | S | Ν | w | FSC | PUD | ST | BL | SL | S | ST | BL | SL | ST | BL | SL | S | ST | BL | SL | s |
| 9/18/2010 | 2210 | | | 6640 | | | | | | | | | | | | | | | | | | | | | |
| 9/28/2010 | 2300 | | | 4030 | 5320 | | | | | | | | | | | | | | | | | | | | |
| 12/20/2010 | | | | 3820 | | | | | | | | | | | | | | | | | | | | | |
| 1/3/2011 | | | | | | 248 | | | 170 | 3580 | | | | | | | | | | | | | | | |
| 3/28/2011 | | | | | | | | | 48 | 968 | | | | | | | | | | | | | | | |
| 4/4/2011 | | | | | | | | | 196 | | | | | | | | | | | | | | | | |
| 10/19/2011 | | | | 269 | 786 | 166 | 94 | | 113 | | | | | | | | | | | | | | | | |
| 11/9/2011 | 830 | | | 205 | 640 | 143 | | 186 | | | | | | | | | | | | | | | | | |
| 1/29/2012 | 1120 | 2010 | 4380 | 110 | 410 | 119 | 66 | | | | | | | | | | | | | | | | | | |
| 5/15/2012 | 475 | | | 133 | 202 | 100 | | | | | 141 | 13 | 14 | 0.5 | 125 | 12 | 11 | 1400 | 696 | 1034 | 870 | 0 | 11 | 47 | 1 |
| 8/31/2012 | 394 | | | 209 | 283 | | | | | | 74 | 25 | 127 | | 70 | 21 | 59 | 1190 | 930 | 1250 | | 0 | 10 | 0 | |
| Average | 1222 | 2010 | 4380 | 1927 | 1274 | 155 | 80 | 186 | 132 | 2274 | 108 | 19 | 71 | 0.5 | 98 | 17 | 35 | 1295 | 813 | 1142 | 870 | 0 | 11 | 24 | 1 |
| # of Samples | 6 | 1 | 1 | 8 | 6 | 5 | 2 | 1 | 4 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 1 |
| Stand. Dev. | 842 | | | 2547 | 1994 | 58 | | | 66 | | | | | | | | | | | | | | | | |

Table 2. COD, TSS, VSS, Alkalinity, and Total Coliform Data from Elsie Site

ST: Septic Tank (Pumping Chamber to Mound after Sedimentation)

ST2: Second Chamber in Second Septic Tank

ST3: First Chamber (Immediately after Wastewater Exits the Milking Facility)

BL: Bark Lysimeter

SL: Soil Lysimeter (2 Feet Below Soil Under Mound)

S: South Trench (Downstream from Mound)

N: North Trench (Upstream from Mound)

W: West Trench (Side of Mound Towards Ridge Road)

FSC: Flooded Sampling Chamber

PUD: Puddle on SW Corner of Mound (Away from Ridge Road)

| Date | | | NH₃ | (mg/L N |) | | | | | NO₃ (m | g/L N) | | | | | | TP (m | g/L) | | | |
|--------------|--------|------|------|---------|-----|-----|-----|------|------|--------|--------|------|------|-----|-----|-----|-------|------|-----|-----|-----|
| | ST | BL | SL | S | w | FC | PUD | ST | BL | SL | s | w | FSC | ST | ST2 | ST3 | BL | SL | s | Ν | FSC |
| 9/18/2010 | 108.00 | 0.7 | | | | | | | 0.41 | | | | | | | | 53 | | | | |
| 9/28/2010 | 48.00 | 3 | 2.2 | | | | | 0.15 | | 0.92 | | | | 47 | | | 53 | 5 | | | |
| 12/18/2010 | | | | | | 0.6 | | | | | | | 6.14 | | | | | | | | |
| 12/19/2010 | | | | | | | | | 2.99 | | | | | | | | | | | | |
| 12/20/2010 | | 0.5 | | | | | | | 2.99 | | | | | | | | | | | | |
| 1/3/2011 | | | | 0.2 | | 0.5 | 0.5 | | | | 0.10 | | | | | | | | 0.4 | | 0.5 |
| 6/26/2011 | | 16 | 29 | 0.2 | | | | | | | | | | | | | 4 | 2 | 0.1 | | |
| 10/19/2011 | | | | | | | | | | | | | | | | | | | | | |
| 11/9/2011 | 94.00 | 1 | 28 | 0.5 | 0.5 | | | 0.10 | 0.26 | 0.24 | 0.53 | 0.31 | | | | | | | | | |
| 1/29/2012 | | | | | | | | | | | | | | 28 | 316 | 342 | 4 | 1 | 0.2 | 0.1 | |
| 5/15/2012 | 115.00 | 6.9 | 0.2 | 0 | | | | 0.13 | 2.72 | 0.35 | 0.26 | | | 89 | | | 19 | 1 | 0.1 | | |
| 8/31/2012 | 63.00 | 1 | 1 | | | | | 0.19 | 0.29 | 0.17 | | | | 238 | | | 74 | 0 | | | |
| Average | 85.60 | 4.16 | 12.1 | 0.2 | 0.5 | 0.6 | 0.5 | 0.14 | 1.61 | 0.42 | 0.30 | 0.31 | 6.14 | 100 | 316 | 342 | 34 | 2 | 0.2 | 0.1 | 0.5 |
| # of Samples | 5 | 7 | 5 | 4 | 1 | 2 | 1 | 4 | 6 | 4 | 3 | 1 | 1 | 4 | 1 | 1 | 6 | 5 | 4 | 1 | 1 |
| Stand. Dev. | 28.99 | 5.69 | 15.0 | 0.2 | | | | 0.04 | 1.42 | 0.34 | 0.22 | | | 95 | | | 29 | 2 | 0.1 | | |

Table 3. Nutrient Data from Elsie Site

ST: Septic Tank (Pumping Chamber to Mound after Sedimentation)

- ST2: Second Chamber in Second Septic Tank
- ST3: First Chamber (Immediately after Wastewater Exits the Milking Facility)
- BL: Bark Lysimeter
- SL: Soil Lysimeter (2 Feet Below Soil Under Mound)
- S: South Trench (Downstream from Mound)
- N: North Trench (Upstream from Mound)
- W: West Trench (Side of Mound Towards Ridge Road)
- FSC: Flooded Sampling Chamber

PUD: Puddle on SW Corner of Mound (Away from Ridge Road)

| Date | | | | Mn (m | g/L) | | | | | | | Fe (m | g/L) | | | | | | As | ; (mg | /L) | | | |
|--------------|-------|-------|-------|-------|------|------|------|------|------|------|-------|-------|------|------|------|-------|----|--------|--------|-------|-----|---|-----|-----|
| | ST | BL | SL | S | Ν | w | FSC | PUD | ST | BL | SL | S | Ν | w | FSC | PUD | ST | BL | SL | s | Ν | w | FSC | PUD |
| 9/7/2010 | 0.41 | | | | | | | | 1.27 | | | | | | | | * | | | | | | | |
| 9/18/2010 | | 3.09 | | | | | | | | 4.80 | | | | | | | | 0.0754 | | | | | | |
| 9/28/2010 | 0.26 | 3.83 | 20.23 | | | | | | 1.27 | 5.35 | 63.28 | | | | | | * | 0.0569 | 0.0575 | | | | | |
| 12/18/2010 | | | | | | | 0.91 | | | | | | | | 3.01 | | | | | | | | * | |
| 12/19/2010 | | 7.75 | | | | | | | | 9.16 | | | | | | | | * | | | | | | |
| 12/20/2010 | | 8.87 | | | | | | | | 9.93 | | | | | | | | * | | | | | | |
| 1/3/2011 | | | | 0.20 | | | 0.48 | 8.96 | | | | 0.16 | | | 1.27 | 7.06 | | | | * | | | * | * |
| 3/28/2011 | | | | | | | 2.36 | 9.70 | | | | | | | 8.24 | 10.09 | | | | | | | * | * |
| 4/4/2011 | | | | | | | 1.21 | | | | | | | | 4.64 | | | | | | | | * | |
| 10/19/2011 | | | | | 0.32 | | | | | | | | 0.33 | | | | | | | | * | | | |
| 11/9/2011 | 0.20 | 3.80 | 6.22 | 0.54 | | 5.01 | | | 0.69 | 0.43 | 63.27 | 0.04 | | 0.56 | | | * | * | * | * | | * | | |
| 5/15/2012 | 0.21 | 2.81 | 3.91 | 3.96 | | | | | 1.04 | 0.38 | 5.85 | 0.63 | | | | | * | * | * | | | | | |
| 8/31/2012 | 39.65 | 23.10 | 53.83 | | | | | | 0.64 | 1.19 | 38.91 | | | | | | * | * | * | * | | | | |
| Average | 8.14 | 7.61 | 21.05 | 1.57 | 0.32 | 5.01 | 1.24 | 9.33 | 0.98 | 4.46 | 42.83 | 0.28 | 0.33 | 0.56 | 4.29 | 8.57 | * | 0.019 | 0.014 | * | * | * | * | * |
| # of Samples | 5 | 7 | 4 | 3 | 1 | 1 | 4 | 2 | 5 | 7 | 4 | 3 | 1 | 1 | 4 | 2 | | 7 | 4 | | | | | |
| Stand. Dev. | 17.61 | 7.23 | 23.01 | 2.08 | | | 0.80 | | 0.30 | 4.01 | 27.20 | 0.31 | | | 2.97 | | | 0.033 | 0.029 | | | | | |

Table 4. Metal Data from Elsie Site

*: Below Detection Limit of 0.05 mg/L, Counted as 0 in Average and Standard Deviation

ST: Septic Tank (Pumping Chamber to Mound after Sedimentation)

BL: Bark Lysimeter

- SL: Soil Lysimeter (2 Feet Below Soil Under Mound)
- S: South Trench (Downstream from Mound)
- N: North Trench (Upstream from Mound)

W: West Trench (Side of Mound Towards Ridge Road)

FSC: Flooded Sampling Chamber

PUD: Puddle on SW Corner of Mound (Away from Ridge Road)

| Date | C | COD (m | g/L) | | Alkalinit | y (mg/L | CaCO₃) | | рН | | Total <i>Coliform</i> (colonies/100 mL) | | | | |
|--------------|--------|--------|------|-----|-----------|---------|--------|------|------|------|--|--------|--------|--|--|
| | ST | Е | w | FC | ST | Е | w | ST | Е | w | ST | E | w | | |
| 7/12/2011 | 2070 | 340 | 298 | | | | | 6.09 | 6.89 | 6.96 | | | | | |
| 7/19/2011 | ` | | | | 3650 | 2370 | 1750 | | | | | | | | |
| 9/8/2011 | | | | | 1063 | | | | | | | | | | |
| 10/20/2011 | 6500 | | | 141 | | | | | | | | | | | |
| 12/13/2011 | 3640 | 217 | 139 | | | | | 6.42 | 6.5 | 6.73 | 1.E+07 | 4.E+04 | 3.E+03 | | |
| Average | 4070 | 279 | 219 | 141 | 2357 | 2370 | 1750 | 6.26 | 6.70 | 6.85 | 1.E+07 | 4.E+04 | 3.E+03 | | |
| # of Samples | 3 | 2 | 2 | 1 | 2 | 1 | 1 | 2 | 2 | 2 | 1 | 1 | 1 | | |
| Stand. Dev. | 2246.1 | | | | | | | | | | | | | | |

Table 5. COD, TSS, and Alkalinity Data from Bath Site

ST: Septic Tank

E: East Trench (Upstream from Mound)

W: West Trench (Downstream from Mound)

FC: Flooded Sampling Chamber

| Table 6. Nutrient Data from Bath Site |
|---------------------------------------|
|---------------------------------------|

| Date | NH ₃ | (mg/L | N) | NO | ₃ (mg/L | . N) | TP (mg/L) | | | | | |
|--------------|-----------------|-------|----|------|---------|------|-----------|-----|-----|--|--|--|
| | ST | Е | w | ST | Е | w | ST | Е | w | | | |
| 7/12/2011 | 156 | 21 | 5 | 0.33 | 1.08 | 0.39 | 37 | 0.1 | 2.7 | | | |
| 7/19/2011 | 196 | 23 | 3 | 0.39 | 0.76 | 0.42 | 30 | 3.5 | 1.8 | | | |
| 12/13/2011 | 60 | 11 | 3 | 0.28 | 0.74 | 5.99 | 485 | 2.8 | 0.8 | | | |
| Average | 137 | 18 | 4 | 0.33 | 0.86 | 2.27 | 184 | 2.1 | 1.8 | | | |
| # of Samples | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | | | |
| Stand. Dev. | 70 | 6 | 1 | 0.06 | 0.19 | 3.22 | 261 | 1.8 | 1.0 | | | |

ST: Septic Tank

E: East Trench (Upstream from Mound)

- W: West Trench (Downstream from Mound)
- FC: Flooded Sampling Chamber

Table 7. Metal Data from Bath Site

| Date | | Mn (r | ng/L) | | | Fe (I | mg/L) | | As (mg/L) | | | | | |
|--------------|------|-------|-------|------|------|-------|-------|------|-----------|---|---|----|--|--|
| | ST | Е | ¥ | FC | ST | Е | w | FC | ST | Е | W | FC | | |
| 7/12/2011 | 0.39 | 16.43 | 10.78 | | 4.72 | 34.10 | 18.95 | | * | * | * | | | |
| 7/19/2011 | 0.50 | 14.59 | 9.23 | | 7.64 | 27.07 | 7.64 | | * | * | * | | | |
| 9/8/2011 | | | | | | | | | | | | | | |
| 10/20/2011 | 0.30 | | | 1.36 | 5.77 | | | 2.58 | * | | | * | | |
| 12/13/2011 | 0.24 | 9 | 3.79 | | 2.33 | 14.52 | 2.63 | | * | * | * | | | |
| Average | 0.36 | 13.34 | 7.93 | 1.36 | 5.12 | 25.23 | 9.74 | 2.58 | * | * | * | * | | |
| # of Samples | 4 | 3 | 3 | 1 | 4 | 3 | 3 | 1 | 4 | 3 | 3 | 1 | | |
| Stand. Dev. | 0.11 | 3.87 | 3.67 | | 2.21 | 9.92 | 8.36 | | | | | | | |

*: Below Detection Limit of 0.05 mg/L

ST: Septic Tank

E: East Trench (Upstream from Mound)

W: West Trench (Downstream from Mound)

FC: Flooded Sampling Chamber

Table 8. Metal Levels in Elsie Bark

| Metal | Concentration (mg/kg) |
|---------|-----------------------|
| Arsenic | <4.7080 |
| Iron | 2723.163 |

| Manganese | 430,7909 |
|-----------|----------|
| Wanganese | 450.7505 |