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Types of Footbath Treatments Used in Northeastern New York, Their Effect on Mini Pit Manure Slurry Ecology and Nutrient Composition, and Forage Grass and Alfalfa Yield and Composition

Project Leaders:

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Background: Non-antibiotic and antibiotic treatments have been employed by dairy producers in footbaths to combat papillomatous digital dermatitis (PDD or hairy heel warts), which causes lameness in dairy cows. A recent article presented 21 available compounds or commercial products that could be used in footbaths for the prevention of PDD (Cook, 2006). Producers have tried many products in footbaths rather than individual hoof topical treatments to reduce cost and increase the efficiency of control. The treatment and prevention of PDD in dairy herds in the United States cost producers money due to decreased milk production, impaired reproductive performance, decreased cow longevity, and the cost of treatment and control methods (Shearer and Hernandez, 2000; Ishler et al., 2001; Cook, 2006). Economic loss will vary depending on the severity of the case, but is generally associated with a minimum cost of $90 to 100 per case (Ishler et al., 2001).

In previous survey work conducted at the W. H. Miner Agricultural Research Institute, Flis et al. (2006) reported that 14 out of 17 farms surveyed in Northeastern NY and Northwestern VT in 2005 were using $CuSO_4$ footbaths for the prevention and control of PDD. It is assumed that the $CuSO_4$ from footbaths is deposited into manure storage systems after use. McBride and Spires (2001) reported manure Cu concentrations for 20 farms in NY and found that the concentrations of Cu in the manures evaluated were above that which could be explained by poor absorption of excess Cu in the ration. Preliminary research has been done on the effect of $CuSO_4$ in manure storage and has shown that when Cu concentration in the manure is increased from 0.14 to 1.05 lb/1000 gallons, the total colony forming units per milliliter of manure were reduced from 136 x 10^5 to 91 x 10^5. The total colony forming units per ml were further reduced to 9 x 10^5 when the Cu concentration of the manure was increased to 1.67 lbs/1000 gallons. Manure test values for Miner Institute have been as high as 2.09 lbs per 1000 gallons. In addition, the trend in manure tested at the University of Vermont Agricultural and Environmental Testing Laboratory has been for increasing copper concentrations on commercial farms since 1998.

Since recent increases in the cost of $CuSO_4$ and concern about increased Cu loading in fields, it is unclear what footbath management strategies are employed on Northeastern NY and Northwestern VT. It is expected that the majority of producers are still using $CuSO_4$ footbaths, due to producer reported efficacy. Further, it is expected that regardless of the product used, after cows have passed through footbaths, they are disposed of to manure storage and subsequently applied to fields. Therefore, the objectives of this study were to first determine the prevalence of the use of footbaths on dairy farms in Northeastern NY and Northwestern VT. Secondly, determine what products are being used, rates of product use, and potential field application rates of the products used. Finally, to our knowledge no research has been done to determine the impact non-antibiotic and antibiotic treatments have on manure storage ecology, nutrient availability, and crop yield and composition.

Survey of Footbath Product Use

Methods:

In January 2007, 375 surveys were mailed to producers in Northeastern NY and Northwestern VT. The mailing list was generated from the William H. Miner Agricultural Research Institute's (Chazy, NY) mailing list for its "Farm Report" and a client list from a dairy veterinary practice in Vermont (St. Albans, VT). Mailing lists were reviewed and producers not in the target region or names known not to be dairy producers were eliminated. Producers were asked to complete and return the surveys by end of February 2007.

Producers were asked to provide contact information to use as follow-up if there were questions about the answers on the survey or to use for possible participation in future research. Producers were then asked to report information on farm characteristics and manure management (Table 1). If producers were using a footbath, there were 7 questions about footbath practices (Table 2).

Survey Interpretation and Analysis- Information collected about the footbath practices on farms was used to calculate the number of footbaths used per year and the total amount of product used per year (Table 3). For farms that reported the amount of product and water used in each footbath, the concentration of product in the footbath was calculated. For farms that did not report total manure spread per year, the expected amount was calculated using the American Society of Agricultural Engineers Standard (2005) of 17.5 gal of manure per cow per day to determine the total manure production per year based on the reported number of lactating cows (Table 3). Manure management data provided was used to calculate the number of acres that receive manure and the application rate for manure per acre (Table 3). Footbath waste field application rates were calculated for farms disposing footbath waste into manure systems (Table 3). Farms that reported total manure spread per year were analyzed separately from calculated estimates for footbath product field application rates.

Categorical data were analyzed using Proc Freq of SAS v. 9.1.3 (SAS Institute, 2003). Numerical data were analyzed using Proc GLM of SAS v. 9.1.3 (SAS Institute, 2003). Data were analyzed to compare farms that used footbaths with farms that did not use footbaths. The statistical comparison of farms and practices by product used was not appropriate due to the low number of farms in some of the groups. Some farms used multiple products and in those cases, the farm was included in the calculations for all products used. Significant differences were declared at $P \leq 0.05$ and tendencies at $P \leq 0.10$.

Results:

Of the 375 surveys mailed, 98 were returned from producers, for a return rate of 26%. No further reminders or follow-up surveys were mailed. Of the 98 returned, 49 were from producers in Northeastern NY and 49 from Northwestern VT.

Summary of all farms:
Farm size averaged 354 (n = 98) lactating cows, 844 (n = 93) tillable acres, and ~5 tillable acres per cow (n = 90) for all farms that returned surveys. When farms were classified based on the revised Confined Animal Feeding Operation rule (2003) for farm size, 15 % were considered large farms (>700 cows), 36 % were medium farms (200 to 699 cows), and 49 % were small (<199 cows). Most farms housed heifers on farm rather than through contract heifer raising operations (94 % versus 6 %, n = 93, respectively $P < 0.001$).

Surveyed farms in Northeastern NY were larger with more lactating cows and tillable acres than farms from Northwestern VT (Table 4). More farms stored manure for an average of 6 months than spread manure daily (85 versus 15%, n = 94, respectively). Farms that reported storing manure in Northeastern NY, also reported having on average fewer months of storage than farms in Northwestern VT (Table 4). Of the 14 farms that reported spreading daily 13 were in Northeastern NY and one was in Northwestern VT where they reported that in the winter manure was stacked and not spread. The use of pits as storage was the most frequently reported method of manure storage (45%, n = 42) followed by lagoons (33%, n = 31). A few of the farms reporting used manure separation (n = 2), pit and separation (n = 1), composting (n = 1), slurry tanks (n = 1), or tanks (n = 1).

Footbath vs. No Footbath:
Most farms responding to the survey used some type of footbath than did not (71 versus 27 farms, respectively $P < 0.001$). In Northeastern NY, 37 farms reported using footbaths and 12 reported not using a footbath. Similar footbath use was reported in Northwestern VT, with 34 farms using a footbath and 15 not using a footbath. Farms using footbaths had more lactating cows and tillable acres than those that did not (Table 4). All farms classified as large (>700 cows) reported using a footbath. For the medium and small farms, 97% and 46%, respectively, reported using footbaths.

Footbath use:
The use of footbaths for lactating cows only was the most frequently reported practice for all farms (Table 6). Farms that reported the use of $ZnSO_4$ in footbaths were the only group to also report the use of footbaths in lactating cows and heifers (Table 6). The low percentage of farms using footbaths for both lactating and dry cows (10%, Table 6) indicates an area for further investigation into hoof management practices prior to and during the dry period.

Products Used (Table 5:
Of the 71 farms using a footbath 47% reported using only 1 product, 45% reported using 2 products, 7% reported using 3 products, and 1% reported using 4 products in footbaths. Overall, 12 different footbath products were reported to be used. The most frequently used products were $CuSO_4$, formaldehyde, tetracycline, and $ZnSO_4$. The finding that $CuSO_4$ was the most frequently used agrees with the survey conducted in 2005 (Flis et al., 2006). Due to the low frequency of use of the other 9 products that were reported, only the top four products were used in the comparison of footbath management and field application practices. The breakdown of footbath product use by farm size is presented in Figure 1. The majority of small and medium farms used $CuSO_4$ in footbaths, while the large farms tended to use either formaldehyde or $CuSO_4$. Interestingly, all farms that reported the use of tetracycline (n = 9) were classified as medium farms.

Product Management Practices (Table 7):
Producers using formaldehyde in footbaths reported using 160 more footbaths per year than producers using $CuSO_4$. The higher number of footbaths on farms that reported the use of formaldehyde is likely related to the larger farm size of these farms resulting in a higher number of lactating cows. Farms that reported using tetracycline or $ZnSO_4$ reported fewer baths per year than did farms that reported the use of $CuSO_4$ or formaldehyde. The large variation in the number of footbaths per year is likely influenced by management decisions on each individual farm due to the incidence rates of PDD and cow numbers. Current guidelines for footbath use are based on herd hygiene scores and no more than 200 to 300 cows passing through a footbath before it is changed (Cook, 2006).

The amount of $ZnSO_4$ used per bath was higher than all other products. The amount of $CuSO_4$ and formaldehyde used in a single footbath was similar, while the amount of tetracycline was the lowest, resulting in the least amount of product imported to the farm each year. The amount of water used per footbath was similar for farms using $CuSO_4$, formaldehyde, and tetracycline, with less water used with $ZnSO_4$.

Footbath Cost:
A concern for producers using footbaths is the cost of the practice. The current prices, as of November 2007, for the top four products reported being used in this survey are: $68 for a 50 lbs bag of $CuSO_4$, $250 for 55 gallons of formaldehyde, $69.99 for 5.5 lbs of tetracycline, and $52 for a 50 lbs bag of $ZnSO_4$. Using these prices and the average amount of product used each year (Table 7), the average total cost per year are $7082, $409, $1213, and $6587, for $CuSO_4$, formaldehyde, tetracycline, and $ZnSO_4$, respectively. When divided by the average number of cows on each farm using the product groups, the annual average cost per cow was $17.92, $0.68, $4.04, and $15, for $CuSO_4$, formaldehyde, tetracycline, and $ZnSO_4$, respectively. The higher number of farms using $CuSO_4$ compared to all other products, despite its high cost may be due to its perceived efficacy for managing PDD. In addition, worker safety concerns may limit the use of formaldehyde, which is indicated as a potential carcinogen. An area for further research is the comparison of the efficacy of these products across farms to determine the most cost effective rate and product.

Potential Field Application Rates for Farms Using Footbaths (Table 8):
Disposal of footbath waste to manure storage accounted for 84% (n = 88) of the disposal methods for the top four products. Disposal of footbaths into manure that was spread daily accounted for 12% (n = 13) of the farms and 2% (n = 2) disposed of footbath waste in both manure storage and daily manure applications. Nearly 100% of all $CuSO_4$, formaldehyde, tetracycline and $ZnSO_4$ footbaths were disposed of to manure that are potentially applied to crop land. The high concentration of Cu in dairy manures may affect the function of the manure storage and availability of nutrients to crops. There is little research available on the effects footbath products have on manure storage function and manure nutrient availability.

In order to more accurately estimate the potential application rate of product to tillable crop acres that receive manure, farms were separated by those that reported the total amount of manure spread and those where total amount of manure spread was estimated. The average potential application rate of $ZnSO_4$ was highest at 12 lbs. per acre. Copper sulfate and formaldehyde had similar application rates at 8 and 7 lbs. per acre, respectively. Understandably, tetracycline had the lowest application rate at less than 0.20 lbs. per acre.

Conclusions/Outcomes/Impacts*:*
There is concern that the application of wastes that contain footbath products may damage crops, effect soil quality, or contaminate surface and ground water supplies. The use of formaldehyde is a health concern due to exposure on the farm at the time of use, however, it does not last a long time when dissolved in water and will not accumulate in plants or animals (ATSDR, 1999). It is not clear how much of the total formaldehyde used in footbaths and disposed of to manure storage is still present at the time of manure application. The calculated potential application rates for tetracycline are lower than the other three products. Research conducted in Minnesota found that soils that had received manure on dairy farms that reported using tetracycline for therapeutic treatments had similar concentrations of antibiotic resistant bacteria present as locations that had never received any manure (Ghosh and LaPara, 2007). Research done with dairy and feedlot manure placed in windrows found that concentrations of less than 2 mg/kg was below the detection limit after 6 months of incubation (Storteboom et al., 2007). These results indicate that there is little potential for large quantities of tetracycline to be applied to fields. However, it is not known if the degradation of tetracycline would be the same in a liquid storage system.

The excess application of both $CuSO_4$ and $ZnSO_4$ is of more concern for potential changes in soil quality, accumulation of the metals in the soil, and potential crop effects. Zinc and Cu are both essential micronutrients for plants. In NY and VT there is a potential for Zn deficiency to occur. Zinc deficiency is common in corn planted in Northeastern NY and Northwestern VT. University of Vermont Extension (2004) and the Cornell Cooperative Extension (Ganoe, 2007) both recommend 2 lbs/acre for sites where soil test Zn is low but no deficiencies have been observed. University of Vermont Extension (2004) recommends 8 to 10 lbs/acre of Zn for sites where deficiency has been observed. The average potential application rate found in this survey was 12.1 lbs/acre of $ZnSO_4$ which is equivalent to 4.9 lbs/acre of Zn. The potential application rates for Zn found here are less than the recommendations for Zn application when Zn deficiency is observed. Additionally, the toxicity threshold for Zn is when plant Zn concentrations are observed above 200 ppm (Whitehead, 2000). These factors combined with the low number of farms that reported the use of $ZnSO_4$ in footbaths, indicate that the practice is of lower concern than the use of $CuSO_4$.

Copper toxicity is not very common and generally occurs after multiple years of high Cu applications from animal manures, sewage sludge, or mineral fertilization (Whitehead, 2000). Once the soil concentration of Cu is toxic, the condition will persist for many seasons due low crop removal rates (Schulte and Kelling, 1999). In general, crops will only remove about 0.1 kg/ha of Cu per year (Schulte and Kelling, 1999). The normal concentration of Cu in plant tissue is between 5 and 20 mg/kg. When plant tissue concentration increase above 20 mg/kg it is expected that toxicity is occurring (Whitehead, 2000). When the potential application rates calculated from this study are converted to elemental Cu, assuming 25% Cu in $CuSO_4 \bullet 5H_2O$, the average elemental Cu application was 1.88 lbs/acre with a maximum of 7.4 lbs/acre. Brock et al. (2006) reported application rates between 6.7 and 7.5 lbs Cu $acre^{-1}$ when Cu application rates from dairy manure were evaluated on an 800 cow dairy in NY. These application rates are within the range of the calculated potential application rates form this survey. The average application rate here is likely lower because it is a calculated value and not based on field application records.

The application rates calculated here were based on the data returned in the surveys for total manure and percent of acres receiving manure and not manure application records per field. It is expected that there were likely some fields on these farms that received more manure per acre per year than the calculated average, which would increase the application of any of the products that are disposed of to manure storage. The established data set from this survey could be used for further investigation into actual application rates, identifying fields for soil testing, forage yield and quality analysis to determine what the impacts of these applications are on soil quality, and forage quality, and forage yields.

From the results of the survey it was determined that $CuSO_4$ was the most frequently reported product used (59 farms), followed by formaldehyde (31 farms) and tetracycline (9 farms) in Northeastern NY and Northwestern VT. As $CuSO_4$ was the most frequently reported product used a larger scale project, which incorporated the application of treated manure to grass plots was designed. The effects of formaldehyde and tetracycline from used footbaths on manure storage was conducted in a smaller scale study.

Copper Sulfate Manure Treatment

Methods:

Twelve mini pits, 70-gallon black plastic tubs, were used to mimic manure pit storage facilities. Mini pits were arranged in 3 rows of 4 tubs and filled with approximately 45 gallons of manure collected from the free-stall alleys of the W. H. Miner Agricultural Research Institute dairy barn to ensure a low initial concentration of copper (Cu).

Copper sulfate was added to mini-pits to achieve concentrations of 0, 1, 2, and 3 lbs Cu/1000 gallons of manure. There were 3 replications per application rate treatment for a total of 12 mini pits. Treatments were mixed according to the protocol of the W. H. Miner Agricultural Research Institute's dairy facility and covered with plywood. Mini pits were left undisturbed for 10 days at which time they were emptied and the manure applied to orchardgrass, timothy, reed canarygrass, and alfalfa plots. While mini pits were being emptied 4 random samples from different depths were taken and composited. All samples were analyzed for bacterial counts, total N, ammonium N, P, K, Ca, Mg, Zn, Fe, Mn, B, ash, and organic matter.

When mini-pits were emptied contents were applied to pure established orchardgrass, timothy, reed canarygrass, and alfalfa plots (15' x 6'). Four treatments with 3 replications were applied (0, 5, 10, and 15 lbs/acre Cu). These treatments were achieved by applying 10.34 gallons of manure per plot of the 0, 1, 2, or 3 lbs/1000 gallon manure treatments to the 0, 5, 10, and 15 lbs/acre plots, respectively. In the spring of 2008 yield will be measured on re-growth of plots. Material sampled from plots will be analyzed for NDF, ADF, lignin, macro and micro minerals, and CP. Additionally, soil samples will be taken from each plot at cutting and analyzed for Cu. PROC GLM of SAS v. 9.1.3 (SAS Institute, 2003) was used to test for the effects of treatment on the bacterial counts and mineral analysis.

Results:

The measured Cu concentration in the mini pits was slightly lower than the planned treatments (Table 9). All treatments were significantly higher than the control (0) and the 3 lbs/1000 gal manure was the highest concentration of total Cu in the manure. The measure of total Cu in the mini pits being lower than the proposed treatments is likely due to the method of incorporating the $CuSO_4$ and water mixture with the manure and the sampling of the mini pits. Some of the Cu may have remained near the surface, not well incorporated with the manure, lowering the concentration of the sample that was taken as the mini pit was emptied.

The analysis of the total mineral concentration of the manure samples showed that there was significantly more Fe in the 1 and 2 lbs/1000 gal manure treatments than in the 0 and 3 lbs/1000 gal manure treatments

(Table 9). While the values were statistically different, this is a small numerical difference, likely making the difference not biologically significant in the mini pits or field application. There were no other significant effects of Cu treatment level on the characteristics or the mineral concentration of the samples. Further, there was no significant effect of Cu treatment on the number of bacteria counted in 1 ml of manure (Table 9).

Conclusions/Outcomes/Impacts:

It was expected that the higher Cu concentrations in the manure would decrease the number of bacteria in the manure due to the antibacterial properties of Cu. The measure of bacteria count done in this project was not selective, so it is not clear if there is possibly a change in the profile of the community due to the addition of Cu. Loss of bacterial numbers or a change in the profile of the community would likely result in difference in the measurements of N concentrations and S concentration, as these are elements that bacteria will interact with that can be lost from the manure in a gas form. There were no differences between the N measurements of the 4 Cu treatment levels (Table 9). However, while not statistically different, there was a slight increase in the concentration of S in the manure as the Cu treatment increased (Table 9). This would indicate less use of S by bacteria and less loss of S in gas forms like hydrogen sulfide (H_2S). Further research is needed to investigate the effects of higher manure Cu concentration on the loss of S from manure storage and possible changes in bacterial population profile that might influence this despite similar total numbers.

Formaldehyde and Tetracycline in Manure Treatment

Methods:

A 4 x 4 Latin square design was used to test two concentrations of formaldehyde and one concentration of tetracycline on the ecology and mineral make-up of manure. For this study 4 gallons of manure was placed in 5 gallon pails and stored in the dairy barn at the W. H. Miner Agricultural Research Institute for 12 days and sampled every 3 days. Manure was collected from the barn alley at the Miner Institute dairy to ensure low initial concentrations of footbath waste. After manure was added to pails, treatments were incorporated. One pail in each row was left as a control with no footbath product added. There were 2 formaldehyde treatments: low (0.0125 ounces/gallon manure, 0.05 ounces/pail) and high (0.04 ounces/gallon, 0.17 ounces/pail). There was one tetracycline treatment of 1.9×10^{-4} ounces/gallon of manure (0.001 ounces/pail). Two treatments, representing the mean of the middle 1/3 and top 1/3 use rates, were used for formaldehyde because more farms reported the use of the product. Only one treatment was used for tetracycline that represented the mean of 5 of the 9 farms that reported use of tetracycline. Four of the farms were not used because the quantity of tetracycline used per bath was not reported, one was an outlier, and one did not report in repeatable units.

Samples were sub-sampled, diluted to 10^{-4} and plated on an R2A agar, a non-selective media, immediately following collection, and allowed to incubate for 48h at 38°C then bacteria growth was assessed. The remainder of the sample was analyzed for DM, ash, ammonia N, total N, total concentration of P, K, Ca, Mg, Mn, Fe, Zn, Cu, and B. Traceability tests for formaldehyde in the samples were run using chromotrophic acid and concentrated H_2SO_4 (Gryllaki-Berger et al., 1992). Concentration of tetracycline remaining in the samples could not be tested. PROC GLM of SAS v. 9.1.3 (SAS Institute, 2003) was used to test for the effects of treatment, day and the interaction of day and treatment.

Results:

Formaldehyde was not able to be detected in samples at either treatment level or any time point. While there were few significant effects of treatment on analytical parameters measured on the manure or the bacterial count in the manure, there was a significant effect of day of sampling in the concentration of S in the manure and the bacterial counts regardless of treatment (Figures 2 & 3). For the concentration of S, as the sampling day increased the concentration of S measured in the manure decreased (Figure 2). This was likely due to the mixing of the manure at each sampling day and the loss of S in gas forms during mixing. The bacterial count of the manure was stable through the first 3 sampling days and then fell off on the final day (day 12) (Figure 3). This is likely due to a decrease in the amount of substrate available for the production of new cells, as no new manure was added to the pails through the experiment.

Conclusions/Outcomes/Impacts:

At the treatment levels that were imposed in this project, formaldehyde and tetracycline had little effect on the general ecology of manure storage system. Further research is needed to determine if the addition of these products is changing the profile of the bacterial populations and what is the function of Fe in manure storage.

Outreach:

Preliminary results for the survey data have been published in the W. H. Miner Agricultural Research Institutes "Farm Report". Results of both studies will be presented at a producer meeting in March of 2008.

Acknowledgement:

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Person(s) to contact for more information (including farmers who have participated:

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Table 1. Layout of questions for farm characteristics and manure management.

Number of lactating cows	
Are heifers housed on the farm?	YES NO
Number of tillable acres	
Percentage of acres receiving manure	
Is manure stored or spread daily? (Circle one)	STORED SPREAD DAILY
If stored what is the manure storage system type? (Circle One)	LAGOON PIT SEPARATED
Manure storage system size (Number of months of storage)	
Amount of manure spread per year (gallons or pounds)	

Table 2. Questions, answer types, and possibilities for information on footbath management practices.

Question	Answer Type	Options
Where is footbath waste disposed of?	Multiple Choice	a. Manure storage system b. Spread daily c. Dumped in area that does not enter manure storage d. Recycled in flush system e. Other
What groups are footbaths used in?	Multiple Choice	a. Lactating cows b. Dry Cows c. Heifers
What products are used in footbaths for all groups of animals?	Short Answer	
At what rate (pounds or gallons per gallon of water) is each product used in a single footbath?	Short Answer	
How frequently is each product used on the farm (number of footbaths per week or month)?	Short Answer	
Are any of the treatments used seasonally? If so which and when are they used?	Short Answer	
Are rates of use changed for any treatments seasonally? If so which ones and what are the differences?	Short Answer	

Table 3. Equations for calculations done from collected data.

Value Calculated	Equation
Number of footbaths, $year^{-1}$	Number of footbaths per week x 52 Number of footbaths per month x 12
Total product used, $year^{-1}$	Amount used per footbath x Number of footbaths per year
Manure produced, $year^{-1}$*	17.5 gal x Number of lactating cows x 365d
Product concentration in manure†	Total product used per year / Total manure per year
Application rate per acre††	Product concentration in manure x manure application rate per acre

*Only calculated for farms that did not report the total amount of manure applied per year.
†Was calculated for all farms, reported manure and calculated manure, but was analyzed separately for 2 groups.
††Was calculated for all farms, reported manure and calculated manure, but was analyzed separately for 2 groups.

Table 4. Least squares means and standard errors for farm size and manure management characteristics of farms in Northeastern NY and Northwestern VT that are either using footbaths (Footbaths) or not using footbaths (No Footbaths).

	Footbaths		**No Footbaths**		***P***		
Item	**NY** (n = 37)	**VT** (n = 34)	**NY** (n = 12)	**VT** (n = 15)	**State**	**Footbath**	**Footbath x State**
Lactating Cows, farm^{-1}	557 ± 66.9	310 ± 43.8	91.7 ± 18.7	64.2 ± 9.52	0.07	<0.001	0.14
Tillable Land, ha • farm^{-1}	1351 ± 157	704 ± 94.8	340 ± 55.4	132 ± 74.3	0.01	<0.001	0.19
Tillable Land Receiving Manure, %	81.9 ± 2.74	87.5 ± 2.56	61.8 ± 10.0	82.5 ± 5.56	0.005	0.007	0.10
Tillable Land Receiving Manure, acre	1050 ± 114	523 ± 70.4	172 ± 20.6	112 ± 73.4	0.03	<0.001	0.09
Manure Storage , mo	5.42 ± 0.66^{a}	7.33 ± 0.45^{a}	4.30 ± 1.51^{b}	7.09 ± 1.16^{a}	0.03	0.04	0.04

^{a,b}Values in the same row with different superscripts are significantly differend at $P < 0.05$

Table 5. Footbath product use on farms in Northeastern NY and Northwestern VT.

Product	Number of Farms Using Product	Percent of All Products
$CuSO_4$	59	50.9
Formaldehyde	31	26.7
Tetracycline	9	7.76
$ZnSO_4$	6	5.17
PedicuRx Trifusion[1]	2	1.72
Soap	2	1.72
IBA[2]	2	1.72
Epson Salt	1	0.86
Salt	1	0.86
George II[3]	1	0.86
UniFresh[4]	1	0.86
PedicuRx[1]	1	0.86

[1]Manufactured and distributed by Westfalia Surge, Naperville, IL.
[2]Manufactured and distributed by IBA, Inc., Millbury, MA.
[3]Manufactured and distributed by Central Petroleum Company, Cleveland, OH.

Table 6. Footbath usage in lactating cows, lactating and dry cows, lactating cows and heifers, heifers only, or all animals for the top four products used on farms in Northeastern NY and Northwestern VT.

	Footbath Treatment				
Group of Animals	**$CuSO_4$** (n = 59)	**Formaldehyde** (n = 31)	**Tetracycline** (n = 9)	**$ZnSO_4$** (n = 6)	**All** (n = 105)*
Lactating Cows	55.9	38.7	77.8	16.7	50.5
Lactating and Dry Cows	8.47	12.9	0.0	16.7	9.52
Lactating and Heifers	13.6	12.9	11.1	33.3	14.3
Heifers Only	3.39	9.68	0.0	0.0	4.76
All Animals	17.0	25.8	11.1	33.3	20.0

*Total is larger than the 98 returned surveys due to the use of multiple products on some farms.

Table 7. Footbath management practices for the top four footbath products used on farms in Northeastern NY and Northwestern VT (mean ± standard error).

Item	Footbath Treatment			
	$CuSO_4$ (n = 59)	**Formaldehyde** (n = 31)	**Tetracycline** (n = 9)	**$ZnSO_4$** (n = 6)
Number of footbaths/yr	244 ± 35.7	404 ± 95.2	129 ± 122	130 ± 23.3
Product use, lbs/footbath	19.3 ± 2.16	18.3 ± 1.87	2.13 ± 1.08	48.4 ± 14.5
Water, gallon/footbath	43.3 ± 4.91	44.7 ± 7.11	41.5 ± 11.2	98.3 ± 51.0
Product concentration, %	5.0 ± 0.4	6.0 ± 0. 6	0.7 ± 0.3	8.0 ± 3.0
Product use, lbs/yr	5207 ± 983	8054 ± 1976	86.7 ± 46.2	6334 ± 2400

Table 8. Manure management characteristics and potential application rates for producers that reported manure applied per year (NC) and producers that total manure applied per year was calculated (C) for each of the top four footbath products use on Northeastern NY and Northwestern VT (mean ± standard error).

Item	**$CuSO_4$**		**Formaldehyde**		**Tetracycline**		**$ZnSO_4$**	
	NC (n = 37)	**C** (n = 21)	**NC** (n = 24)	**C** (n = 6)	**NC** (n = 6)	**C** (n = 3)	**NC** (n = 5)	**C** (n = 1)
Tillable Land, acres/farm	1044 ± 143	869 ± 163	1348 ± 189	1252 ± 375	712 ± 144	1885 ± 1110	888 ± 208	1277
Tillable Land Receiving Manure, acres/farm	811± 105	715 ± 132	1077 ± 127	1080 ± 329	589 ± 106	1606 ± 940	680± 191	945
Total Manure Applied, millions gal/yr	5.97 ± 1.05	1.94 ± 0.33	7.93 ± 1.25	3.30 ± 0.72	2.60 ± 0.88	2.80 ± 1.28	8.82 ± 4.41	3.38
Average Manure Applied, 1000 gal/acre	9.50 ± 0.22	3.43 ± 0.28	8.09 ± 0.94	3.79 ± 0.44	4.86 ± 1.17	2.89 ± 0.58	14.1 ± 4.11*	3.98
Potential Product Application Rates, lbs/acre	7.55 ± 1.51	8.37 ± 2.68	7.34 ± 1.67	6.89 ± 2.76	0.16 ± 0.08	0.03 ± 0.0007	12.1 ± 4.22	5.58

*Higher than others due to one farm that is spreading on a very low percentage (50%) of tillable ha.

Table 9. Lsmeans for manure characteristics, total mineral analysis, and bacterial counts of manure from $CuSO_4$ treated mini pits.

	Treatment (lbs Cu/1000 gal manure)					
Item	**0**	**1**	**2**	**3**	**SE**	***P***
pH	7.2	7.1	7.1	7.2	0.11	0.86
Total Solids, %	13.0	13.4	13.2	12.6	0.42	0.62
Density, lbs/gal	8.0	7.9	7.9	8.0	0.09	0.64
DM, %	12.8	13.2	12.7	12.7	0.43	0.79
Total N, lbs/1000 gal	32.9	31.8	31.4	31.8	0.71	0.50
Ammonia N, lbs/1000 gal	13.5	13.8	13.2	13.6	0.49	0.89
Organic N, lbs/1000 gal	19.4	18.0	18.1	18.2	0.70	0.52
P, lbs/1000 gal	5.0	4.8	4.8	4.8	0.07	0.36
K, lbs/1000 gal	19.4	19.0	19.2	19.8	0.33	0.46
Mg, lbs/1000 gal	9.2	9.1	8.8	8.8	0.22	0.57
S, lbs/1000 gal	3.9	4.3	5.8	4.7	0.66	0.30
Fe, lbs/1000 gal	0.66	0.74	0.79	0.67	0.03	0.03
Cu, lbs/1000 gal	0.07	0.89	1.63	2.58	0.32	0.004
Ash, %	13.0	12.7	13.3	13.4	0.31	0.39
Bacterial Count, x 10^5	68.8	70.3	50.3	63.7	1.31	0.70

Table 10. Lsmeans for manure characteristics, total mineral analysis, and bacterial counts of manure from formaldehyde and tetracycline treated mini pits by treatment.

	Treatments					
Item	**0**	**Low F**	**High F**	**Tet**	**SE**	***P***
DM, %	14.0	13.9	14.1	14.6	0.16	0.04
Total N, lbs/1000 gal	21.8	22.1	21.8	23.0	0.47	0.26
Ammonia N, lbs/1000 gal	12.2	12.0	14.0	13.1	0.96	0.50
Organic N, lbs/1000 gal	9.60	10.1	7.81	9.98	1.09	0.45
P, lbs/1000 gal	4.23	4.32	4.16	4.40	0.12	0.54
K, lbs/1000 gal	20.8	19.5	20.6	19.7	0.62	0.37
Mg, lbs/1000 gal	5.47	5.46	5.44	5.72	0.13	0.38
S, lbs/1000 gal	3.74	3.67	3.72	3.68	0.11	0.96
Fe, lbs/1000 gal	0.61	0.58	0.55	0.62	0.02	0.10
Cu, lbs/1000 gal	0.05	0.05	0.05	0.06	0.001	0.30
Zn, lbs/1000 gal	0.20	0.20	0.19	0.21	0.006	0.47
Ash, %	11.5	11.9	11.4	10.3	0.39	0.07
Bacterial Count, log x 10^5	14.0	14.0	14.0	14.1	0.12	0.85

Low F = Low Formaldehyde treatment, High F = High Formaldehyde treatment, Tet = Tetracycline treatment.

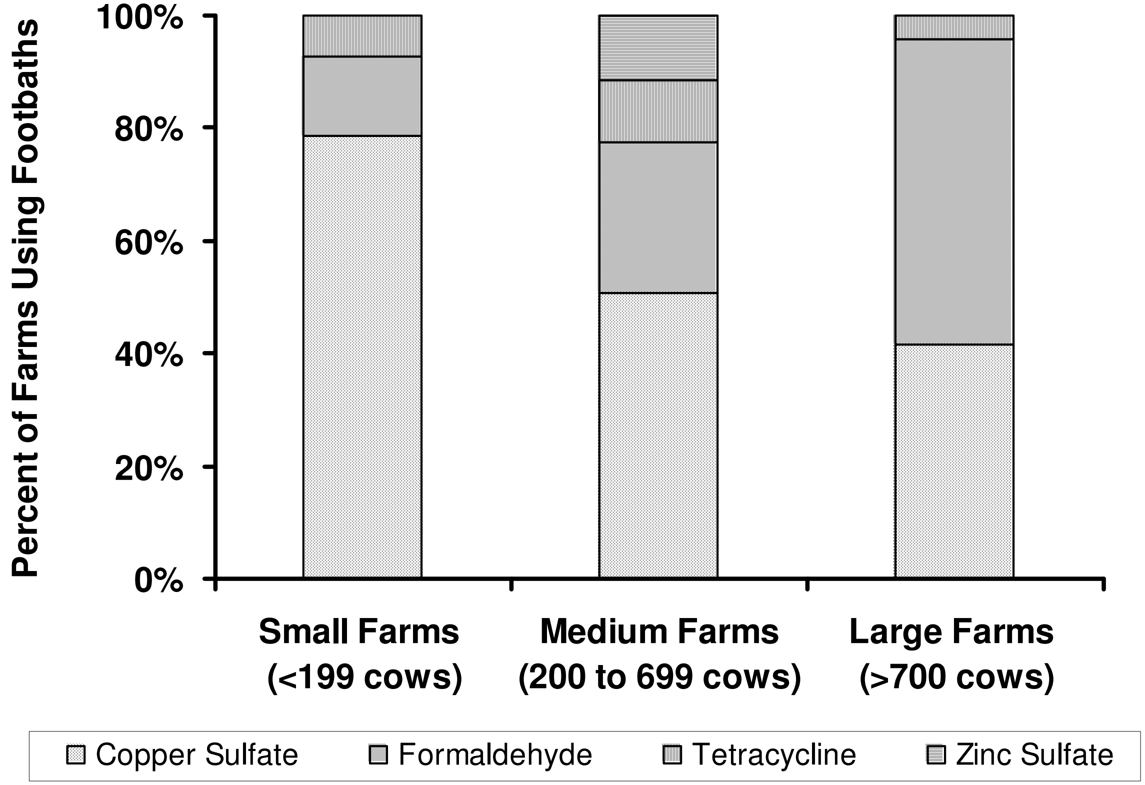

Figure 1. Percent of small, medium and large farms reporting the use of $CuSO_4$, formaldehyde, tetracycline, and $ZnSO_4$ in footbaths.

Table 8. Manure management characteristics and potential application rates for producers that reported manure applied per year (NC) and producers that total manure applied per year was calculated (C) for each of the top four footbath products use on Northeastern NY and Northwestern VT (mean ± standard error).

	$CuSO_4$		**Formaldehyde**		**Tetracycline**		**$ZnSO_4$**	
Item	**NC** (n = 37)	**C** (n = 21)	**NC** (n = 24)	**C** (n = 6)	**NC** (n = 6)	**C** (n = 3)	**NC** (n = 5)	**C** (n = 1)
Tillable Land, acres/farm	1044 ± 143	869 ± 163	1348 ± 189	1252 ± 375	712 ± 144	1885 ± 1110	888 ± 208	1277
Tillable Land Receiving	811± 105	715 ± 132	1077 ± 127	1080 ± 329	589 ± 106	1606 ± 940	680± 191	945

Manure, acres/farm								
Total Manure Applied, millions gal/yr	5.97 ± 1.05	1.94 ± 0.33	7.93 ± 1.25	3.30 ± 0.72	2.60 ± 0.88	2.80 ± 1.28	8.82 ± 4.41	3.38
Average Manure Applied, 1000 gal/acre	9.50 ± 0.22	3.43 ± 0.28	8.09 ± 0.94	3.79 ± 0.44	4.86 ± 1.17	2.89 ± 0.58	14.1 ± 4.11*	3.98
Potential Product Application Rates, lbs/acre	7.55 ± 1.51	8.37 ± 2.68	7.34 ± 1.67	6.89 ± 2.76	0.16 ± 0.08	0.03 ± 0.0007	12.1 ± 4.22	5.58

*Higher than others due to one farm that is spreading on a very low percentage (50%) of tillable ha.

Table 9. Lsmeans for manure characteristics, total mineral analysis, and bacterial counts of manure from $CuSO_4$ treated mini pits.

	Treatment (lbs Cu/1000 gal manure)					
Item	**0**	**1**	**2**	**3**	**SE**	***P***
pH	7.2	7.1	7.1	7.2	0.11	0.86
Total Solids, %	13.0	13.4	13.2	12.6	0.42	0.62
Density, lbs/gal	8.0	7.9	7.9	8.0	0.09	0.64
DM, %	12.8	13.2	12.7	12.7	0.43	0.79
Total N, lbs/1000 gal	32.9	31.8	31.4	31.8	0.71	0.50
Ammonia N, lbs/1000 gal	13.5	13.8	13.2	13.6	0.49	0.89
Organic N, lbs/1000 gal	19.4	18.0	18.1	18.2	0.70	0.52
P, lbs/1000 gal	5.0	4.8	4.8	4.8	0.07	0.36
K, lbs/1000 gal	19.4	19.0	19.2	19.8	0.33	0.46
Mg, lbs/1000 gal	9.2	9.1	8.8	8.8	0.22	0.57
S, lbs/1000 gal	3.9	4.3	5.8	4.7	0.66	0.30
Fe, lbs/1000 gal	0.66	0.74	0.79	0.67	0.03	0.03
Cu, lbs/1000 gal	0.07	0.89	1.63	2.58	0.32	0.004
Ash, %	13.0	12.7	13.3	13.4	0.31	0.39
Bacterial Count, x 10^5	68.8	70.3	50.3	63.7	1.31	0.70

Table 10. Lsmeans for manure characteristics, total mineral analysis, and bacterial counts of manure from formaldehyde and tetracycline treated mini pits by treatment.

	Treatments					
Item	**0**	**Low F**	**High F**	**Tet**	**SE**	***P***
DM, %	14.0	13.9	14.1	14.6	0.16	0.04
Total N, lbs/1000 gal	21.8	22.1	21.8	23.0	0.47	0.26
Ammonia N, lbs/1000 gal	12.2	12.0	14.0	13.1	0.96	0.50
Organic N, lbs/1000 gal	9.60	10.1	7.81	9.98	1.09	0.45
P, lbs/1000 gal	4.23	4.32	4.16	4.40	0.12	0.54
K, lbs/1000 gal	20.8	19.5	20.6	19.7	0.62	0.37
Mg, lbs/1000 gal	5.47	5.46	5.44	5.72	0.13	0.38
S, lbs/1000 gal	3.74	3.67	3.72	3.68	0.11	0.96
Fe, lbs/1000 gal	0.61	0.58	0.55	0.62	0.02	0.10
Cu, lbs/1000 gal	0.05	0.05	0.05	0.06	0.001	0.30
Zn, lbs/1000 gal	0.20	0.20	0.19	0.21	0.006	0.47
Ash, %	11.5	11.9	11.4	10.3	0.39	0.07
Bacterial Count, log x 10^5	14.0	14.0	14.0	14.1	0.12	0.85

Low F = Low Formaldehyde treatment, High F = High Formaldehyde treatment, Tet = Tetracycline treatment.

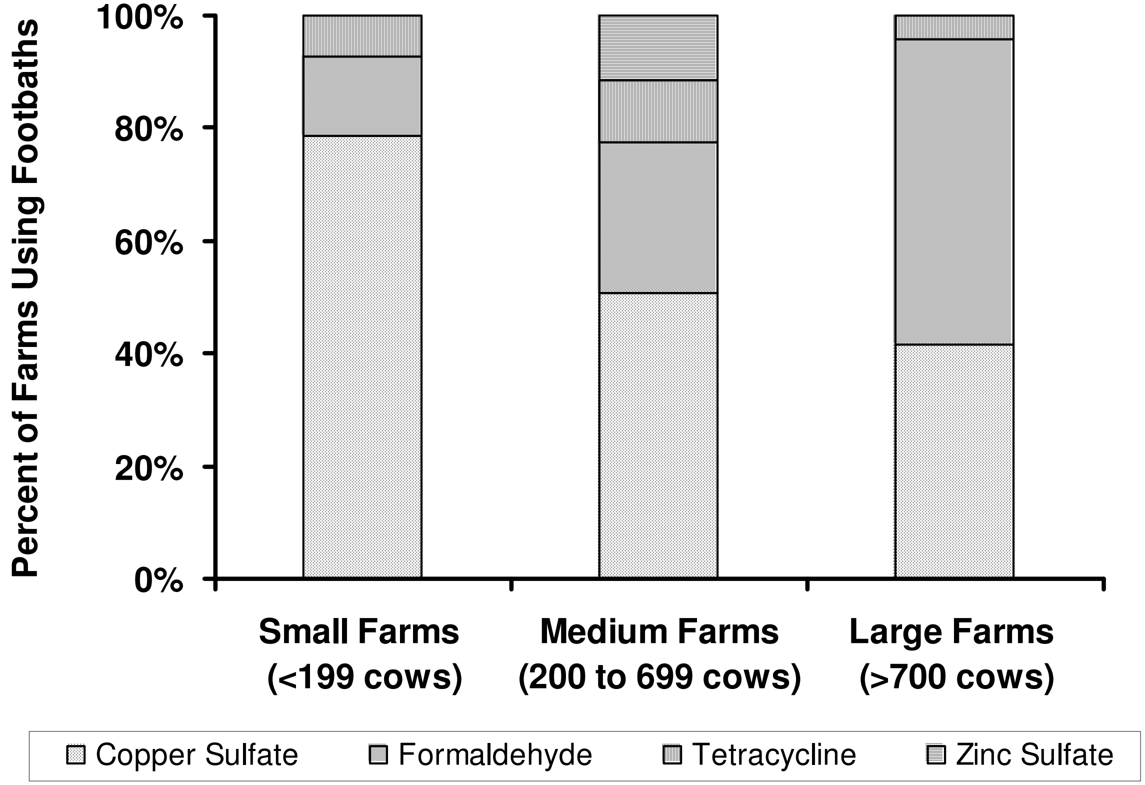

Figure 1. Percent of small, medium and large farms reporting the use of $CuSO_4$, formaldehyde, tetracycline, and $ZnSO_4$ in footbaths.

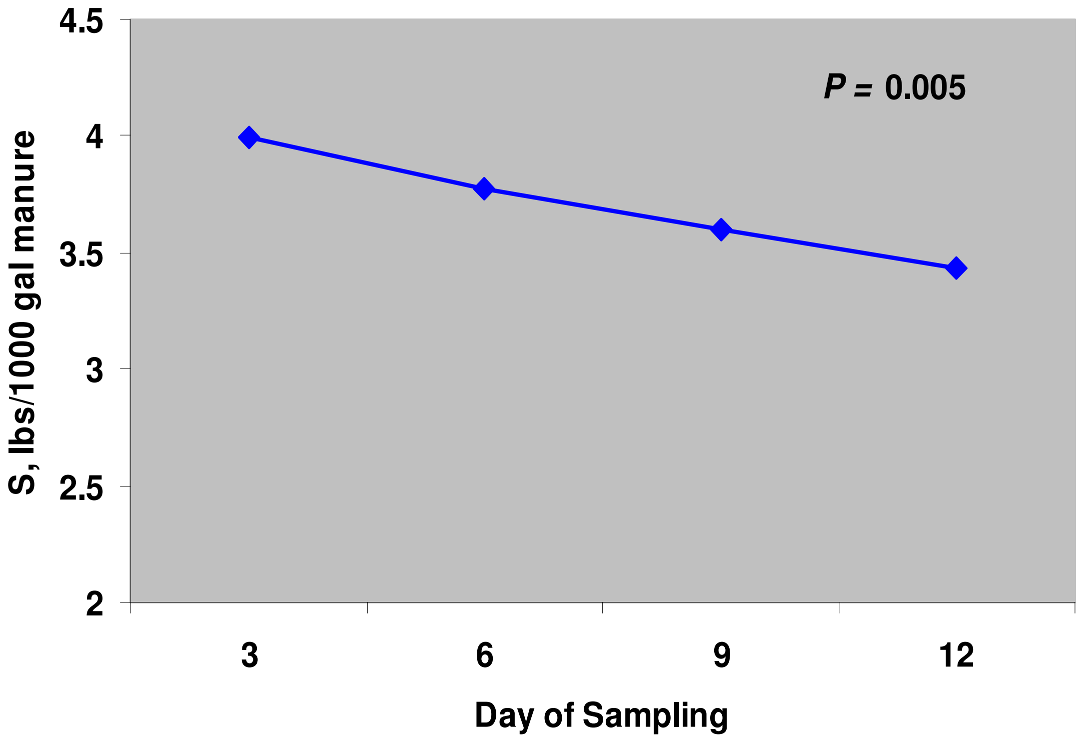

Figure 2. Change in S (lbs/1000 gal manure) over sampling days (average of the Control, Low Formaldehyde, High Formaldehyde, and Tetracycline treatments).

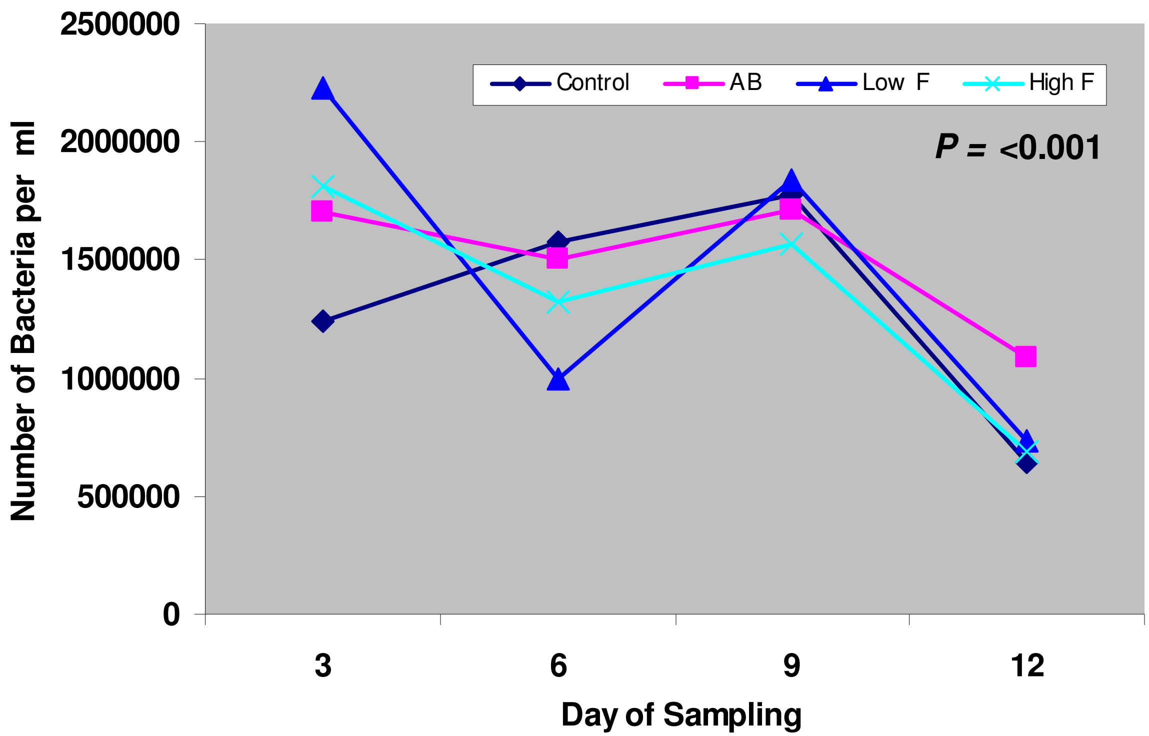

Figure 3. Change in Bacteria Count (count/1 ml manure) over sampling days (average of the Control, Low Formaldehyde, High Formaldehyde, and Tetracycline treatments).