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FECAL COLIFORM RELEASE FROM CATTLE FECAL DEPOSITS[1]

Michael Kress and Gerald F. Gifford[2]

ABSTRACT: Cowpies molded to a standard configuration and size were subjected to simulated rainfall, and the fecal coliform counts were determined using the most probable number (MPN) method of enumeration. The standard cowpie deposits were exposed to simulated rainfall once at ages 2 through 100 days. The effects of rainfall intensity and recurrent rainfall were also tested. Naturally-occurring fecal deposits were also tested to compare their results with those from the standard cowpies.

A log-log regression was found to describe the decline in peak fecal coliform release with fecal deposit age. The 100-day-old fecal deposits produced peak counts of 4,200 fecal coliform per 100 milliliters of water. This quantity of release is minimal compared to the release from fresher fecal material.

Rainfall intensity had little effect on peak fecal coliform release from fecal deposits that were 2 or 10 days old. At age 20 days the effect of rainfall intensity was significant; the highest intensity gave the lowest peak counts, and the lowest intensity gave the highest peak counts. The effect of rainfall intensity appears to be related to the dryness of the fecal deposits.

Peak fecal coliform counts were significantly lowered when the fecal deposits were rained on more than once. This decline was thought to be produced by the loss of bacteria from the fecal deposits during the previous wettings.

Standard cowpies produced a peak release regression that was not significantly different from the regression for the natural fecal deposits. Apparently, grossly manipulating the fecal deposits did not significantly change the release patterns.

(KEY TERMS: fecal coliforms; bacterial water quality; grazing impacts.)

INTRODUCTION

The link between water and the spread of disease was first discovered in 1854 when John Snow demonstrated the relationship between human cholera and the water supply. Since that time, it has been substantiated that water is a vehicle for the transmission of some infectious diseases from host to new host (Diesch, 1970).

Diesch (1970) listed nine human diseases that are transmitted by water-borne bacteria of animal origin. These are: salmonellosis, leptospirosis, brucelosis, tuberculosis, anthrax, colibacillosis, erysipelas, tetanus, and tularemia. Salmonellosis is the major zoonotic disease in humans in the United States. It is widespread in the feces of food producing animals, and surface water serves as a vehicle for transmission (Diesch, 1970). Geldreich (1970) concluded that warm-blooded animals are a link to the occurrence of pathogenic microorganisms in polluted waters. Fecal coliforms (FC) are often used as an indicator of fecal contamination in water (Geldreich, 1970).

Cattle production on rangelands and pastures appears to account for a significant amount of non-point source water pollution; however, there is not total agreement on this point. Buckhouse and Gifford (1976) found no significant difference in indicator bacteria numbers between a grazed and an ungrazed, semiarid, rangeland pasture. Robbins (1979) found that pollution yields were not directly related to the amount or characteristics of animal wastes, but he found that the concentration of pollutants was dependent on hydrogeological factors.

Bohn and Buckhouse (1981) found that grazed sites had higher fecal coliform (FC) counts than ungrazed sites; they also found that FC concentrations were diurnal and seasonally cyclic in the stream they were studying. Stephenson and Street (1978) found that FC in a rangeland stream increased after cattle were introduced, and the bacterial counts remained high for three months after the cattle were removed.

The Department of Biology and Agricultural Engineering, North Carolina State University (1971), found that grazing on agricultural land increased bacterial pollution in the stream much less than would be expected with the quantity of animal waste. Stephenson and Rychert (1982) found that *Escherichia coli* was two to 760 times more concentrated in the bottom sediment of southwestern Idaho streams than in the overlying water. Darling (1973) investigated the effects of livestock grazing on wildland water quality; he found the absolute maximum counts of indicator organisms to occur during grazing periods. Doran and Linn (1979) found, on Nebraska pasture land, that FC was 5 to 10 times higher in the runoff from grazed areas than from ungrazed areas.

Milne (1976) investigated a western livestock wintering operation, and concluded that if cattle are dispersed they have little impact on the stream, but there is significant bacterial contamination when high-density livestock activities are allowed adjacent to a stream. Several studies of mountain streams concluded that grazing significantly increased bacteria

[1] Paper No. 83128 of the *Water Resources Bulletin*.
[2] Respectively, Graduate Research Assistant, and Professor and Chairman, Watershed Science Unit, Range Science Department, College of Natural Resources, Utah State University, UMC 52, Logan, Utah 84322.

counts in nearby streams (Darling and Coltharp, 1973; Coltharp and Darling, 1975; Johnson, *et al.*, 1978; Kunkle and Meiman, 1968; Morrison and Fair, 1966; Petersen and Boring, 1960).

To evaluate the effect of cattle fecal deposits on water quality, it is important to know how long fecal material serves as a potential source of pollution (Springer and Gifford, 1980). Very few studies have been conducted to determine bacterial survival in cow feces, and even less is known about the release of bacteria from cow feces. Buckhouse and Gifford (1976) found that fecal coliforms persist in cow feces at least seven weeks under hot, dry summer range conditions. Clemm (1977) found there was an initial increase in the number of indicator bacteria in cow feces for the first two weeks, and by the fifth week the bacteria were back to their initial levels. He also found high fecal coliform (FC) levels in the fecal deposits after a year. Thelin and Gifford (1983) found FC release from cattle fecal deposits was still well above recreational water-quality criteria after 30 days (assuming no dilution).

The objectives of this study were to determine the peak FC release from cattle feces as a function of fecal-deposit unrained on age, recurrent rainfall events, different types of fecal deposits, and with varying rainfall intensities.

MATERIALS AND METHODS

This study was conducted during June, July, and August of 1981 at the Green Canyon research area near the Utah State University campus. The site is in North Logan, Utah, at an elevation of 1400 meters.

The fecal deposits used were either naturally-occurring fecal deposits (dung piles) or standard cowpies as developed by Thelin and Gifford (1983). All cattle feces were obtained from Hereford heifers fed a diet of alfalfa hay plus mineral supplements.

Average weight of a fresh, naturally-occurring fecal deposit was determined by weighing 100 fresh fecal deposits (dung piles). The mean weight was 1.24 kg, and any naturally-occurring fecal deposit approximating this weight was considered eligible for use in this study.

Standard cowpies were made by collecting fresh fecal material, mixing it in a cement mixer for 15 minutes, weighing out 0.91 kg of the mixed feces, and forming the cowpie in a 0.20-meter diameter cake pan. Notwithstanding the "humorous" aspect of using "standard cowpies," they provided valid, replicable units.

All fecal deposits were transported to the Green Canyon research area where they were placed on a very thin layer of sand that covered the soil surface. The sand avoided the problem of soil accumulating on the bottom side of fecal deposits. The fecal deposits were covered with a plastic tarpaulin when natural rain occurred. Monthly mean minimum temperatures at the study site ranged from 8.7 to 11.6°C while the mean maximum temperatures ranged from 25.4 to 30.8°C. Monthly evaporation from a Class A standard evaporation pan ranged from 172 mm in June to 232 mm in August.

The study consisted of six treatments as follows: a 100-day treatment, a dung-pile treatment, a recurrent-rainfall treatment, and three rainfall-intensity treatments.

The 100-day treatment was designed to study FC release as a function of unrained on age of fecal deposits. It served as the control for the recurrent-rainfall and the dung-pile treatments, and it was also used as one of the rainfall intensity treatments. The fecal deposits for this treatment were rained on once at ages 2, 10, 20, 30, 40, 50, 70, or 100 days (9 replications per age class). Three replications underwent simulated rainfall for 25 minutes each, and the runoff was sampled at 5-minute intervals to determine peak FC release time. The six remaining fecal deposits were sampled only at the time of predetermined peak release.

The dung-pile treatment was designed to determine if there were significant differences in peak FC release patterns between natural fecal deposits and standard cowpies. The dung piles were rained on once at ages 2, 10, 20, 30, 40, or 50 days (9 replications per age class).

The recurrent-rainfall treatment was used to determine the effect on peak FC release of having fecal deposits rained on more than once. These fecal deposits were rained on 6 times at ages 2, 10, 20, 30, 40, and 50 days (9 replications per age class).

The intensity treatments were designed to determine if rainfall intensity was a significant factor in peak FC release. Rainfall intensities were 23 mm/hr, 51 mm/hr, and 69 mm/hr. All other treatments used a rainfall intensity of 51 mm/hr. The intensity treatment cowpies were rained on once at ages 2, 10, or 20 days (9 replications per age class per rainfall intensity).

The rainfall was produced by a modular-type drop-forming rainfall simulator as modified by Malekuti and Gifford (1978). The simulator was elevated to a height of 3.7 m, and the raindrop fall area was protected by a canvas windscreen. A collection board, designed by Thelin and Gifford (1983), was placed under the rainfall simulator. Average drop size was about 3.0 mm and, based on data presented by Laws (1941), the drops reaching approximately 80 percent of terminal velocity. The rainfall simulator was calibrated daily at the rainfall intensities to be used that day.

Water used for producing simulated rainfall came from the North Logan City water supply, and was dechlorinated by the addition of a sufficient quantity of a 10 percent sodium thiosulphate solution ($Na_2S_2O_3$) solution, as recommended in Standard Methods (APHA, 1975).

Runoff samples were collected in whirl-pak bags at the appropriate times over 30-second intervals from a trough drain pipe. The 30-second time period was necessary to provide sufficient volume of sample water. Collection was initiated 15 seconds prior to the mark and completed 15 seconds after. Once collected, the bags were immediately placed in a styrofoam cooler for transport to the lab.

Between runs, the platform on which the fecal deposits were placed was thoroughly cleaned and disinfected by scrubbing with chlorine bleach and rinsing with a 10 percent solution of $Na_2S_2O_3$. In order to check this clearing procedure, several blank runs were made during the sampling period. This involved raining on the empty, but just cleaned, platform and taking samples as usual. The amounts of fecal coliforms in these runoff samples were found to be insignificant.

Bacterial Analysis

After the day's test runs, the samples were brought back to the lab for immediate bacteriological analysis. The most probable number (MPN) method (APHA, 1975) was used instead of the membrane filter method for reasons of practicality. The close proximity of the sample deposit to the runoff collection point resulted in a sufficient amount of organic debris being present in the sample water to clog the membrane filters.

RESULTS

The 100-day aging treatment showed a decline in peak FC release with unrained on fecal-deposit age (Figure 1). A log-log transformation of the peak FC data yielded a regression with an R^2 of 0.923. Thelin and Gifford's (1983) peak FC counts were compared to the regression determined in this study. All of their peak FC points fell within the regression confidence interval (Figure 1).

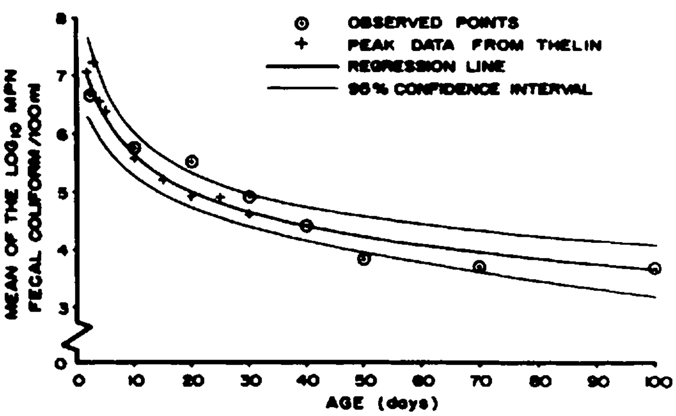

Figure 1. The 100-Day (unrained on age), Log-Log Regression of Peak Fecal Coliform Release from Standard Cowpies. The equation for day 2-100 is: Log Y = 7.57–1.97 Log X, R^2 = 0.923. Thelin and Gifford's (1983) peak release data are also shown.

The peak FC counts of the recurrent-rainfall treatment were consistently lower than their once-wet counterparts (Figure 2). This difference was significant on the third, fourth, and fifth wettings, but the difference was not significant on the second or sixth wettings.

The FC release from natural dung piles differed significantly from the release from standard cowpies only at ages 2 and 50 days. The regressions of the natural dung-pile treatment and the standard cowpie treatment were not significantly different, however (Figure 3).

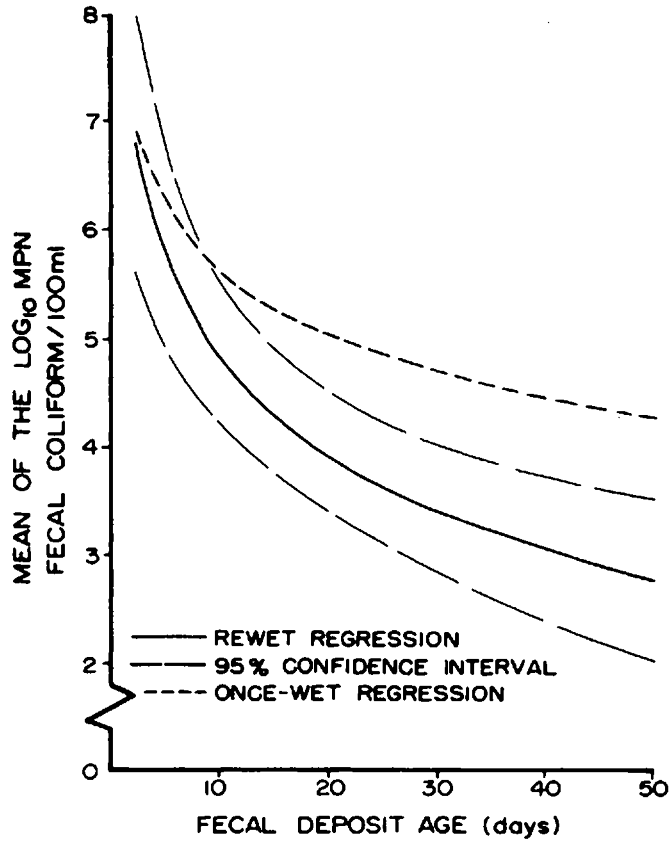

Figure 2. Log-Log Regression of Peak Fecal Coliform Release from Rewet Standard Cowpies Compared to Log-Log Regression from Once-Wet Standard Cowpies. Equation for the rewet regression is: Log Y = 7.69-2.88 Log X, R^2 = 0.925.

There were no significant differences among the three rainfall intensity treatments at day 2 or day 10, but there were significant differences at day 20 (Figure 4). At day 20, the low rainfall intensity treatment had the highest peak FC release, and the high rainfall intensity treatment had the lowest peak FC release. The timing of peak FC release varied with rainfall intensity at day 20. The high-intensity treatment reached a peak at 10 minutes; the mid-intensity treatment reached a peak at 15 minutes; and the low-intensity treatment did not peak before 25 minutes (Figure 5). The 20-day low rainfall intensity treatment remained below 300 FC per 100 ml for the first 15 minutes, and the count rose sharply at 20 minutes (Figure 5). The 2-day and 10-day rainfall intensity treatments did not show this degree of delayed response (Figures 6 and 7).

DISCUSSION

Fecal deposits that are 100 days old are still a potential source of FC; their release exceeds recreation water quality criteria (assuming no dilution). However, it would require the FC release from approximately 1000 100-day-old fecal deposits to equal the release from one 2-day-old fecal deposit.

Hundred-day-old feces may not be significant in terms of peak release when fresh feces are being deposited. Even the release from 50-day-old cow feces may not be significant compared to the FC release from fresh feces; it requires 125 50-day-old fecal deposits to equal the peak release from one 2-day-old fecal deposit.

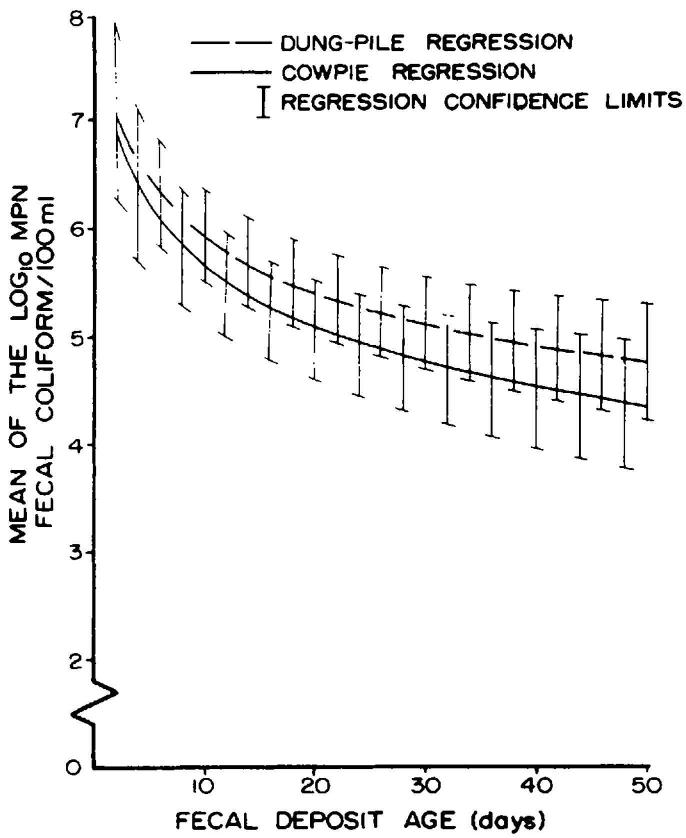

Figure 3. The Log-Log Regression for Natural Dung Piles was not Significantly Different from the Regression for Standard Cowpies. Confidence intervals are at 95 percent level.

Recurrent rainfall produced peak FC counts below the release level of once-wet fecal deposits (Figure 2). This may be due to a significant number of FC being leached from the fecal deposits during the previous wettings. Geldreich (1966) indicates the average gram of fresh cow feces contains about 2.3×10^4 FC; this would mean that a fresh standard cowpie should contain about 2.1×10^8 FC. The 2-day-old standard cowpies were calculated to have released 2.16×10^8 FC at the end of 25 minutes of simulated rainfall. Although the theoretical number is only a generalization, the 2.16×10^8 FC released appears to be a significant loss.

The regression for the standard cowpie was not significantly different from that for the natural dung-pile (Figure 3). This is not surprising if FC release is a function of the initial FC numbers in the fecal deposit. Initial FC numbers are proportional to the fecal-deposit weight (Geldreich, 1966). The natural dung piles weighed an average of 37.5 percent more (fresh weight) than a standard cowpie, so presumably the dung piles initially contained 37.5 percent more FC than the standard cowpies. A 37.5 percent difference is difficult to detect when the non-transformed coefficient of variation was as high as 220 percent and never fell below 65 percent.

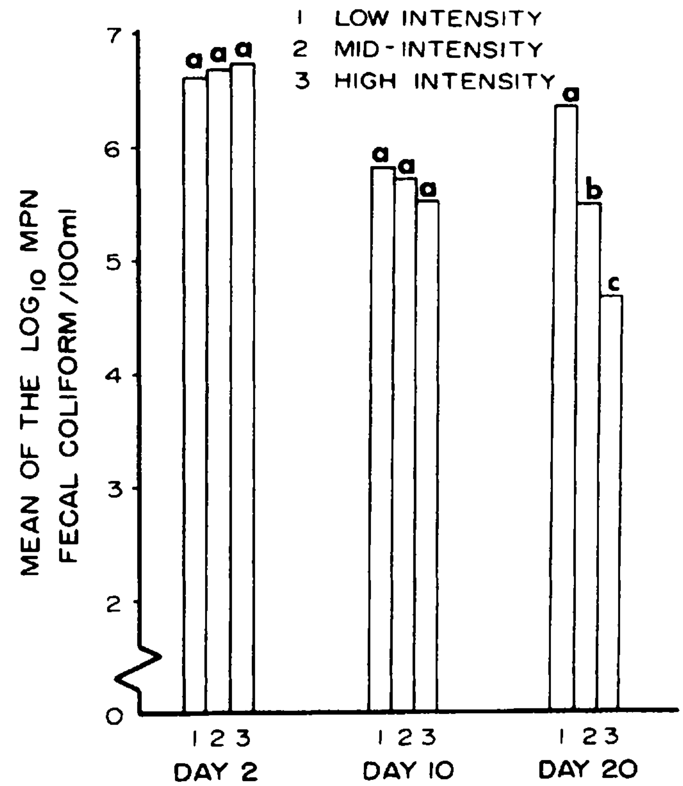

Figure 4. Peak Fecal Coliform Counts from Standard Cowpies at Three Rainfall Intensities (23, 51, and 69 mm/hr, respectively). Significance is indicated at 0.05 level.

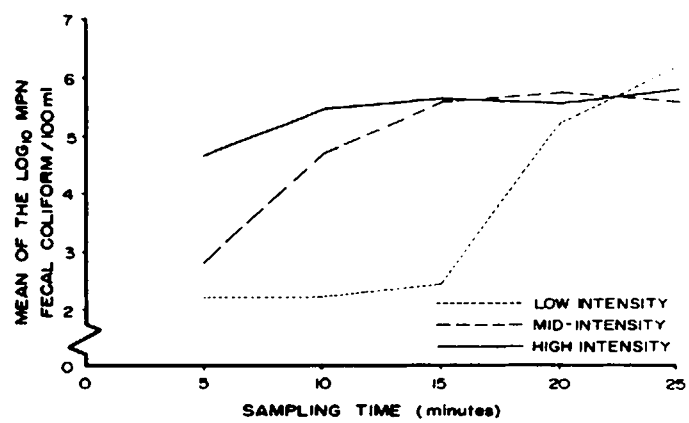

Figure 5. Fecal Coliform Counts at 5-min. Intervals for Three Rainfall Intensities (23, 51, and 69 mm/hr) Using 20-Day-Old (unrained on age) Standard Cowpies.

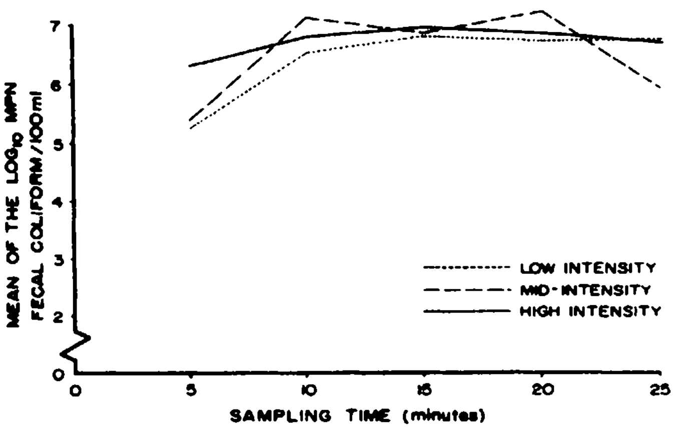

Figure 6. Fecal Coliform Counts at 5-min. Intervals for Three Rainfall Intensities (23, 51, and 69 mm/hr) Using 2-Day-Old (unrained on age) Standard Cowpies.

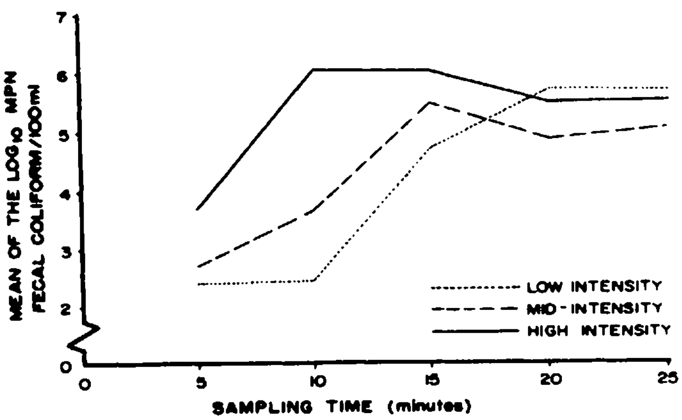

Figure 7. Fecal Coliform Counts at 5-min. Intervals for Three Rainfall Intensities (23, 51, and 69 mm/hr) Using 10-Day-Old (unrained on age) Standard Cowpies.

Rainfall intensity did not significantly impact FC release at day 2 or day 10 (Figure 4); this coincided with the ages when standard cowpies were still partially moist. At day 20, when the standard cowpies were completely air dry, rainfall intensity was significant. The volume of rainfall after 15 minutes of low-intensity rain equaled the volume of rainfall after 5 minutes of high-intensity rain. Yet the 20-day, high-intensity treatment showed significant response at 5 minutes while the 20-day, low-intensity treatment showed little response at 15 minutes (Figure 5). This low-intensity, delayed response may indicate that rainfall intensity can affect the flow path through a dry fecal deposit.

CONCLUSIONS

A study was undertaken during the summer of 1981 to examine fecal coliform release from cattle feces under field conditions. Specific concerns were fecal coliform release as influenced by: 1) the not-rained-on age of the fecal deposit, 2) recurrent rainfall, 3) rainfall intensity, and 4) natural dung piles vs. standard cowpies.

The following conclusions were reached:

1. Hundred-day-old, unrained on fecal deposits produced FC counts that exceeded recreational water quality criteria, but the release from these fecal deposits was minimal when compared to the release from 2-day-old unrained on fecal deposits.

2. The regression, Log Y = 7.57 – 1.97 Log X, was the most appropriate regression for predicting FC release from once-wet fecal deposits.

3. Recurrent rainfall reduced the peak FC release below the peak release levels of the once-wet fecal deposits.

4. Standard cowpies did not differ significantly from natural dung piles in FC release patterns, so the standard cowpie regression can be used to determine the FC release from naturally occurring fecal deposits.

5. Rainfall intensity is only significant after the fecal deposits are completely air dry. Then, the lower the rainfall intensity, the later and higher the peak counts.

ACKNOWLEDGMENTS

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