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EVALUATION OF THE WATER QUALITY IMPACTS OF LAND APPLICATION OF POULTRY LITTER

Research Project Technical Completion Report
Project G-1549-02

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ABSTRACT

EVALUATION OF THE WATER QUALITY IMPACTS OF LAND APPLICATION OF POULTRY LITTER

Evaluating the effect of land application of animal waste on water quality is fraught with inherent variability due to differing infiltration rates, slope, rainfall intensity and etc. Simulated rainfall technology has been used in erosion research for decades. Generally, this technology is used on plots of sufficient size (25 x 5 m) to develop rill and inter-rill erosion. The object of this investigation was to adapt and modify existing rainfall simulation technology used in soil erosion research for use in evaluating water quality impacts of land application of animal waste, and to test, evaluate and demonstrate it's scientific validity. State of the art simulation technology was obtained from the National Soil Erosion Research Laboratory located on the campus of Purdue University. The technology was scaled (2 x 6 m) and modified to fit into field research programs having several treatments and replicated plots. The technology was shown to meet specification needed to produce the required raindrop size and velocity, flexibility in storm intensity, while maintaining uniformity (> 0.8). Equally important, the unit is portable and fits well into labor intensive runoff work requiring replication of a variety of treatments.

T. C. Daniel and D. R. Edwards

Completion Report to the U.S. Department of the Interior, Geological Survey, Reston, VA, June 1991.

Keywords: Surface Runoff/Water Quality/Ground Water/Solute Transport/Vadose Zone

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INTRODUCTION

Integrated poultry production is currently concentrated in the southern region of the U.S. Arkansas, Georgia, North Carolina, and Alabama account for over 40% of national cash receipts derived from the sale of poultry products; Arkansas leads all states in both quantity and cash value of poultry products (NASS, 1989). As southern states are crucial to national poultry production, levels of poultry production are similarly important to the economic well-being of these states - cash receipts from poultry and eggs constituted 41% and 43% of total 1988 farm income for Arkansas and Alabama, respectively (NASS, 1989). Dense confinement and production of concentrated fecal waste are inherent characteristics of efficient integrated poultry production systems. The broiler waste produced in Arkansas per year is estimated to be in excess of one million dry metric tons. The traditional method of waste disposal is land application without incorporation, a practice potentially detrimental to the quality of ground and surface water. The potential for water quality degradation from eutrophying nutrients (nitrogen and phosphorus), oxygen-demanding materials (organic carbon), pesticides, and selected metals is particularly high, especially in areas such as Northwest Arkansas where shallow, cherty soils and karstic geology greatly increase interaction between surface and ground water.

Rainfall is the fundamental force behind runoff and erosion, the mechanisms of nonpoint source pollution. Efforts to understand and minimize the effects of land application of litter on water quality should begin with an understanding of how rainfall is related to the causative processes. Unfortunately, it is quite challenging to relate its causes if the rainfall is supplied naturally because natural rainfall is extremely variable in terms of time of occurrence, depth, and intensity. These rainfall characteristics may have a significant impact on the design of runoff experiments, but they are almost completely unpredictable.

Researchers are increasingly using simulated rainfall in controlled, small-scale runoff experiments to avoid the uncertainties associated with natural rainfall. The use of simulated rainfall in preference to natural rainfall also has the advantages of facilitating more rapid acquisition of results and better control of the experiment. However, a rainfall simulator must meet the following requirements in order to be a practical research tool and for the results to be meaningful (Meyer, 1965): (a) drop-size distribution and fall velocities comparable to those of natural rainfall, (b) capability of simulating a wide range of intensities, (c) sufficient application area, (d) uniformity of intensity and drop characteristics throughout the application area, (e) nearly continuous rainfall application, (f) near-vertical angle of drop impact, (g) accurate reproduction of storms, (h) satisfactory operation in windy conditions, and (i) portability.

A. Purpose and Objectives.

The overall objective of this research was to quantify the effects of land application of poultry waste on runoff and ground water quality. Development of such cause and effect relationships in a field setting requires rigorous attention to an experimental design that minimizes the inherent variability in runoff and leaching investigations. The use of accepted simulated rainfall techniques is fundamental to the production of statistically useful event related runoff and leaching data. Developing, testing and obtaining this capability, however, requires considerable investment in staff time, labor and materials. Without this capability, however, scientists must rely on natural rainfall which varies between and during storm event. Because of this, many years of natural event data are required, and even then the inherent variability may be so high that identification of clear statistical differences may be impossible. With the simulated rainfall technique, however, scientists can control and replicate events and dramatically increase the probability of demonstrating statistical significance. The primary objective of this research was to develop and evaluate rainfall simulation technology capable of meeting the above requirements.

B. Related Research and Activities:

The use of simulated rainfall technology has been around for a number of years (Meyer, 1965), steadily evolving to a point that several options exist for the scientist.

The principal investigators reviewed the strength and weakness of each option and decided on an existing prototype developed at the USDA-ARS National Soil Erosion Research Laboratory located on the campus of Purdue University (West Lafayette, IN).

After an onsite visit one unit was transported to the University of Arkansas campus for duplication, modification and testing.

METHODS AND PROCEDURES

A. Description of Rainfall Simulation:

Simulated rainfall is delivered to the ground surface from four VeeJet 80150 nozzles, manufacturing by Spraying Systems Company, Inc. These particular nozzles are often used for rainfall simulation because the resultant drop-size distribution, when operated at an exit pressure of 6 psi, is comparable to that of natural rainfall. The nozzles must be elevated 3 m above ground level to ensure drop velocities approximately equal to terminal velocity. The nozzles are attached to a shaft (driven by an electric motor) and oscillates across openings in the aluminum simulator body. The opening dimensions are selected to ensure that the drop trajectories are nearly vertical. The geometry of the openings and operating characteristics of the nozzles result in an effective coverage area of 1.5 by 6 m. The four nozzles are placed in line and thus cover a plot having dimensions of 1.5 by 6 m.

Different simulated rainfall intensities are obtained by varying the frequency at which the nozzles oscillate across the openings. An electric clutch is installed between the electric motor and shaft, causing the shaft to turn (and the nozzles to oscillate) only when the clutch is energized although the motor runs continuously. The clutch is controlled by a timer circuit which allows selection of a range of oscillation frequencies and, therefore, simulated rainfall intensities. When the clutch is not energized and the nozzles are spraying to the sides of the openings, the water drains from the simulator body and can be returned to the water source.

Water is supplied to the simulator from an aluminum storage tank which may be filled from any source desired. A pressure regulator is placed between the pump and simulator to maintain the correct nozzle exit pressure.

An aluminum scaffold holds the rainfall simulator at the correct distance above the ground. The scaffold has adjustable legs so that vertical distances may be precisely set on nonuniform soil slopes. The scaffold legs are fitted with collars so that two rods or pipes may be used to move the scaffold and simulator without disturbing the plot underneath. The scaffold also has a rectangular aluminum frame attached to the top. Tarps are fastened to this frame and staked to the ground to form a wind screen for the simulator and prevent rainfall pattern distortion due to high winds.

B. Evaluation and Testing.

Four rainfall simulators were constructed and tested. The simulators were calibrated by applying simulated rainfall to a plastic-covered plot having dimensions of 1.5 by 6 m. After the rate of runoff had stabilized, a container was placed at the outlet of the lot and used to collect the runoff. The time required to collect a given volume of water was measured to allow the computation of average simulated rainfall intensity occurring on the plot. This procedure was repeated for a range of nozzle oscillation frequencies, enabling establishment of the calibration curve. Figure 1 shows the calibration curve obtained for one of the rainfall simulators (curves for the other three simulators were identical and therefore not shown). As illustrated, simulated rainfall intensities from zero to 15 cm per hour are possible, depending on the nozzle oscillation frequency.

Uniformity of the simulators was assessed by capturing the rainfall in containers placed on 30 cm spacings throughout the 1.5 by 6 m application area. The intensity used during the uniformity tests was approximately 5 cm per hour, and this intensity was maintained for roughly 10 minutes. After cessation of simulated rainfall, the quantities of water in the containers were determined and a uniformity coefficient computed for each simulator. Uniformity coefficients ranged from 80% to 82%, which is well within the range of acceptable uniformity coefficients reported by developers of other, more complex rainfall simulators. Figure 2 demonstrates a typical application pattern for cross sections of the plot located at 1.5, 3, and 4.5 feet from the down slop end of the plot. The higher intensities at the center of the plot are characteristic of single-row nozzle rainfall simulators. When two or more simulators are operated side-by-side, as would be the case in applying rainfall to larger plots, the overlap from the simulators will greatly enhance the cross sectional uniformity of application. The high uniformity coefficients, however, allow the simulators to be used singly as well as in combination.

PRINCIPAL FINDINGS AND SIGNIFICANCE

Four rainfall simulators were developed for nonpoint source pollution research. The operating characteristics were evaluated and found to meet all requirements of research-based rainfall simulation equipment. Since formal testing, the simulators have been used to apply simulated rainfall to a total of 95 plots. The water delivery system and nozzle oscillation frequency controller were configured to enable independent operation of each simulator. Most often, however, all four simulators operated simultaneously. All simulators performed well with minimal maintenance.

CONCLUSION:

Simulated rainfall technology is available that meets specifications required to produce raindrop size and velocity, flexibility in storm intensity, while maintaining acceptable uniformity. Equally, the technology is portable and fits well into labor-intensive runoff work requiring replication of a variety of treatments.

LITERATURE CITED

Meyer, L.D. 1965. Simulation of rainfall for soil erosion research. Transactions of the ASAE 8(1):63-5.

NASS, National Agricultural Statistics Service. 1989. Poultry production and value. Bulletin POU 3-1 (April). USDA, Washington, D.C.

Niebling, W.H., G.R. Foster, R.A. Natterman, J.D. Nowlin, and P.V. Holbert. 1981. Laboratory and field testing of a programmable plot sized rainfall simulator. Proc. Symp. on Erosion and Sediment Transport Measurement, Florence, Italy. Int. Assoc. Hydrologic Sci. Pub. No. 133.

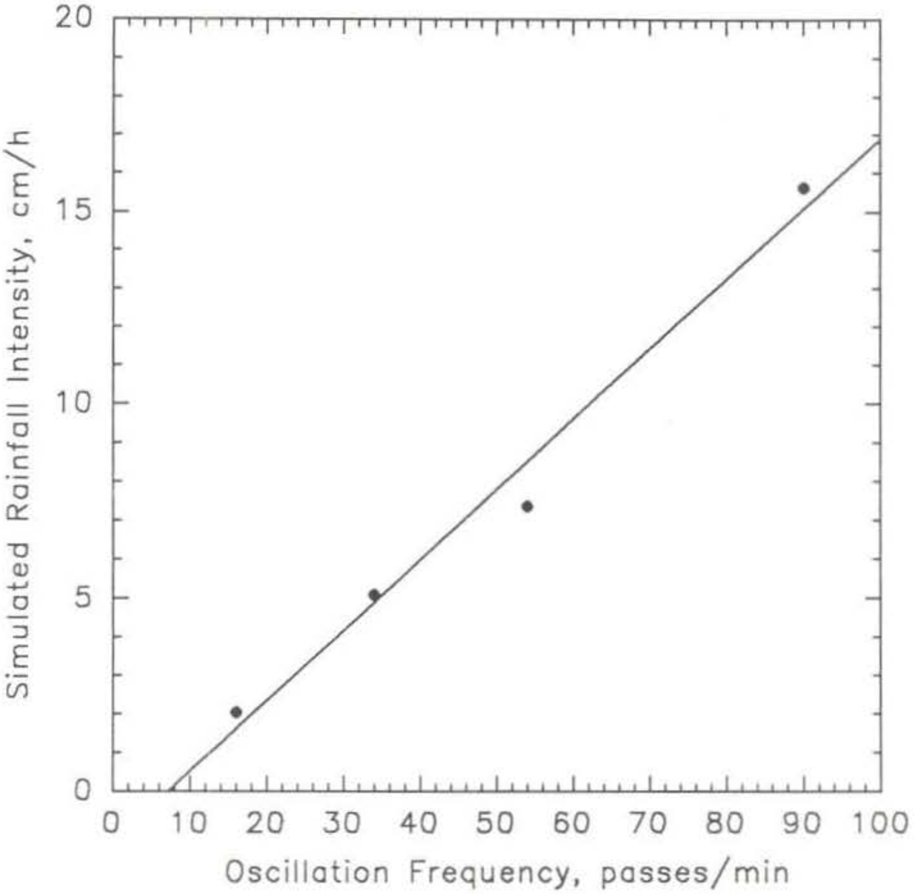

Figure 1. Rainfall simulator calibration curve.

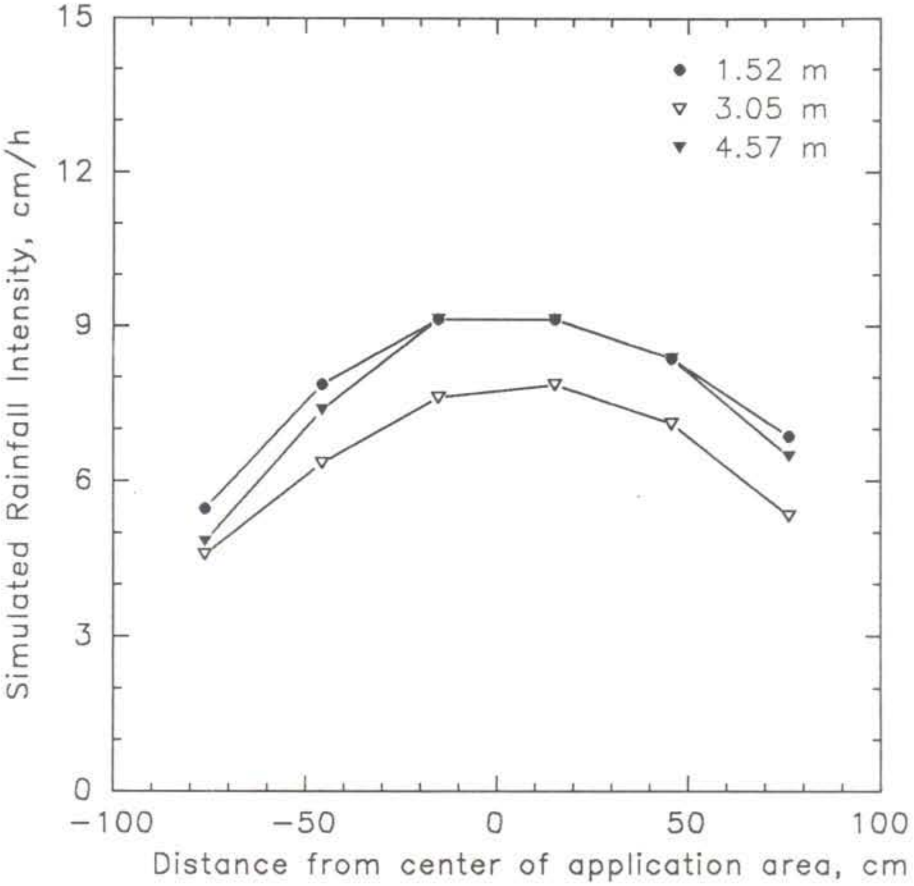

Figure 2. Simulated rainfall uniformity for cross sections at 1.5, 3.0, and 4.5 m from down slope end of plot.