

WATER QUALITY IMPACTS OF POULTRY LITTER LAND APPLICATION

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REFERENCE: *Proceedings of the 1995 Georgia Water Resources Conference*, held April 11 and 12, 1995, at The University of Georgia, Kathryn J. Hatcher, Editor, Carl Vinson Institute of Government, The University of Georgia, Athens, Georgia.

Abstract. The objective of this study was to quantify any differences in specific water quality parameters between a forested watershed, similar watersheds whose land use is dominated by poultry production and open lands that receive applications of poultry litter. Four streams in The Lake Lanier drainage basin were selected for sampling. The data collected during this study do not provide strong evidence that the high concentrations of poultry houses and the associated land application of litter are contributing to a degradation of the water quality in the streams that were monitored. Almost all of the significant differences were associated with Mud Creek, and these differences are likely due to the discharge of municipal waste treatment plant effluent into the stream. High levels of fecal coliform and fecal streptococci bacteria have been noted previously in the streams in the Lake Lanier watershed. This study also showed high levels of bacteria in the water. The levels were high, however, for all of the sites, including Little John which is, on the whole, undeveloped.

INTRODUCTION

The Lake Lanier drainage basin covers approximately 665,600 acres in North Georgia and is the primary source of domestic water for the city of Atlanta. The drainage basin is located in the heart of the poultry producing region of the state with an estimated 274 million birds produced or housed within the basin. These birds could produce as much as 274,000 tons of litter per year.

Chicken litter can be a valuable source of fertilizer for agricultural crops. However, if it is improperly applied or managed, it could become a source of pollutants in the streams in the basin and, ultimately, in Lake Lanier and the water supply of Atlanta. Lake Lanier also represents the upper reaches of the Chattahoochee River, the quantity and quality of which is currently the source of considerable mutual concern to the states of Georgia, Alabama, and Florida.

The potential for poultry litter to cause degradation of the water quality in the lake has caused many action agencies concern. Considerable time and effort has been expended by many persons discussing this "problem" and how to address it. Programs are being developed in order to assist farmers in environmentally sound management of the tremendous volumes of poultry litter generated within the basin. Some studies, however, have indicated that proper application and management of poultry litter will not cause water quality impairment (Magette, 1988).

The potential for negative water quality impacts from improper management of poultry litter is widely recognized. There exists, however, little if any data to show that the poultry litter, as currently managed, is actually causing a problem. Without this information it is impossible to assess the actual benefits of adopting alternative management practices such as stack houses for litter storage and composting of dead birds. Informed decisions regarding protection of Lake Lanier will require specific data relating the types of land uses

and accompanying management practices to water quality in adjacent streams and, ultimately, Lake Lanier.

RESEARCH APPROACH

A study was undertaken to quantify any observed differences in specific water quality parameters between a forested watershed and three other watersheds which contain high poultry production and the accompanying land application of poultry litter to nearby crop and pasture lands. Four watersheds within the Lake Lanier watershed were selected for monitoring. The streams that were selected for monitoring represented portions of the Little John, West Little River, East Little River, and Mud Creek watersheds. The Little John Creek was selected as the control site, *i.e.* a predominately forested watershed with no concentrated animal production activities. The Mud Creek site was the only monitored stream which would receive runoff from urban areas and receives the effluent from a wastewater treatment plant operated by the City of Cornelia, GA. All watersheds are part of the Upper Chattahoochee River watershed (USGS Hydrological Unit 031301).

The area consists of sloping to steeply sloping soils derived from acid crystalline and metamorphic rocks. Upland soils in the watersheds are primarily represented by two soil associations. Eighty five percent or more of the area soils are classified as Pacolet-Gwinnett-Madison Association (10-25% slopes) and 10-15 percent classified as Cecil-Madison-Applying-Gwinnett (2-10% slopes) (Upper Chattahoochee River Soil and Water Conservation District, 1979, Resource Conservation Program and Action Plan, p. 26).

Automated samplers were installed to collect samples of the streams of each watershed on eight-hour intervals. These samples were analyzed for ammonia, nitrate, orthophosphate, chemical oxygen demand, and total suspended solids. During the weekly sample collection, field measurements were made of pH, electrical conductivity, and temperature. Additional samples were collected at this time for determination of the five-day biochemical oxygen demand (BOD₅), fecal coliforms, and fecal streptococci.

The sampling station on the Little John Creek was located approximately 150 m NW of Skitts Mountain Road. This site was selected because the drainage area above the site contained few human and animal interferences. Approximately 91% of the watershed is forested and 8% is in pasture. It was selected to be a control: no poultry were produced in this watershed. The drainage area above the monitoring site at this location is small (248 ha) compared to the other three drainage areas. Some of the forest and pasture overgrowth has been or is being removed. The pasture land in the valley appeared to be in relatively good condition. Seven houses are located so that all or part of the associated runoff waters enter upstream of the sampling location. It is also possible that subsurface flow from septic tanks at these residences could reappear as stream flow prior to the monitoring site.

The East Little River and West Little River sites (4403 and 4864 ha drainage areas above sampling points, respectively) are those sites used in a Clean Lakes study done for Lake Lanier and reported in Nearing, *et al.*, 1992. The sampling location on West Little River was approximately 100 m south of Jess Helton Road. There is a USGS monitoring station (# 02332830) located on West Little River where it is crossed by Jess Helton Road. The sampling location on East Little River was approximately 25 m north of Honeysuckle Road. These watersheds contain about 50% forest land and 40% pasture. Both watersheds contain less than 7% each of residential and crop land uses. The residential areas are low density suburban/rural with septic tanks. According to local USDA NRCS personnel, all cropland is farmed using conservation tillage practices and all dairy operations have no-discharge waste handling systems. The West Little River watershed contains 87 chicken houses, five dairies and eight animal waste lagoons. The East Little River watershed contains 35 chicken houses, four dairies and two animal waste lagoons.

The Mud Creek sampling site was located approximately 200 m northwest of Crane Mill Road. This watershed is smaller (3702 ha) than the East and West Little River watersheds. It contains approximately 50% forest lands and 36% pasture. Approximately 5% of the watershed is in each of the residential and cropped land uses and approximately 3% urban land use. The Mud Creek watershed above the sampling point contains 43 chicken houses and two animal waste lagoons. A 3 mgd treatment plant serves the City of Cornelia and discharges directly into the stream. In a 1992 publication (DNR, 1992), Mud Creek was noted to have pollution problems. Mud Creek, at a location upstream of the location used in this study, was also sampled two times during the study by Nearing, *et al.*, 1992.

These areas have been included in the Water Quality Improvement Program as well as the other Agricultural Conservation Programs. The total area under study is part of an area where there is a large concentration of poultry operations, and the disposal of the associated wastes are assumed to contribute to potential water quality problems. According to a report by the USDA (1989), stream bank erosion as well as road bank erosion contribute significantly to the sediment loads entering the streams.

Sampling Procedures

Automated water samplers were installed to collect samples from the outlet streams of each watershed. A strainer was supported approximately 150 mm above the bed of the stream at each site. The strainer was connected to the automated sampler through a length of Tygon tubing encased in flexible steel electrical conduit (to discourage chewing by wildlife). Each sampler contained 24 437 ml glass sample bottles pretreated with 2 ml H₂SO₄ to reduce sample pH and serve as a preservative. The samplers were programmed to collect samples every eight hours. The samples were collected and transported on ice to the laboratory at weekly intervals. These samples were analyzed for ammonia (NH₃), nitrate (NO₃), orthophosphate (PO₄), chemical oxygen demand (COD), and total suspended solids (TSS). In general, the samples were composited to produce one sample per week. Samples that were collected following runoff producing rainfall events were analyzed individually in order to better resolve the water quality changes that occur following these events.

When samples were collected from the automated samplers, three additional samples were collected from each stream. One sample was collected for determination of the 5-day carbonaceous biochemical oxygen demand (BOD). A second sample was collected in a sterile whirl-pak bag for determination of fecal coliform and fecal

streptococci. A final sample was also collected for on-site determination of pH, electrical conductivity, dissolved oxygen, and temperature.

Immediately upon return to the laboratory, the analyses for BOD, fecal coliforms, and fecal streptococci were initiated. The preserved samples were stored on ice until analysis on the day following collection. All sample analyses were conducted in accordance with methods described in *Standard Methods for the Analysis of Water and Waste Water* (APHA, 1993). Colonies of fecal coliforms (*E. coli*) and fecal streptococci were enumerated using the membrane filtration method. All positive samples were confirmed. Orthophosphate, COD, ammonia, and nitrate were analyzed using spectrophotometric methods and test kits developed by the Hach Company.

The samplers were installed and sample collection was initiated on August 16, 1993.

RESULTS AND DISCUSSION

Total precipitation was 911 mm during the period covered by this report. Ambient temperatures ranged from -15 °C in January, to 36 °C in August. Stream temperatures ranged from 1°C in January to 25°C in August.

The mean values of pH for the three streams were significantly different ($\alpha=0.01$, ANOVA). The mean pH values of the streams were 6.9, 7.1, 7.3, and 7.4 for Mud Creek, Little John Creek, East Little River, and West Little River, respectively. The mean pH of the monthly samples from the East and West Little Rivers in 1991, as reported by Nearing, *et al.* (1992) was 6.9 at both locations. The two pH values reported by Nearing, *et al.* (1992) for Mud Creek were 7.3 and 7.4. The EPA criterion for pH is 6.5-9.0 for freshwater aquatic life (Viessman, *et al.*, 1993).

Electrical conductivity is an indirect measure of the concentration of dissolved salts in the water. The higher the EC, the greater the concentration of dissolved salts. The mean electrical conductivities of the four streams are significantly different. The mean conductivities of Little John Creek, East Little River, West Little River, and Mud Creek were 0.032, 0.046, 0.052, and 0.092 millimhos/cm, respectively. The mean conductivity of 12 monthly samples from 1991 reported by Nearing, *et al.* (1992) for the East and West Little Rivers were 0.052 and 0.059 millimhos/cm, respectively. The two conductivity values reported by Nearing, *et al.* (1992) for Mud Creek were 0.058 and 0.068 millimhos/cm. A report by the U.S. Geologic Survey (USGS, 1991) indicated that during the water years 1987-89, the EC of the Chattahoochee River near Cornelia had a median value of 0.028 millimhos/cm.

An adequate supply of dissolved oxygen (DO) is required to support propagation of fish and other aquatic life. The EPA minimum for DO concentrations in surface waters is 5 mg/l. The dissolved oxygen concentrations in the four streams were not significantly different. The mean DO concentrations were 9.6, 9.8, 10.3, and 10.6 mg/l in Mud Creek, Little John Creek, East Little River, and West Little River, respectively. The mean DO concentrations of the 12 monthly samples from 1991 reported by Nearing, *et al.* (1992) for the East and West Little Rivers were 7.2 and 7.3 mg/l, respectively. The two DO values reported by Nearing, *et al.* (1992) for Mud Creek were 6.2 and 7.3 mg/l in June and September, respectively. The average DO values reported by Nearing, *et al.* (1992) include the warm summer months when warm water temperatures will cause lower DO readings. The average DO values reported in this study do not include values from March through July. Mud Creek is slower and deeper than the other streams. In addition, it receives some BOD

load from a wastewater treatment plant and urban runoff from Cornelia, GA. The median DO concentration for the Chattahoochee River near Cornelia (USDA, 1991) was reported to be 9.1 mg/l. Due to the topography and geology of the area, which cause high velocities and shallow stream depths, streams in the Upper Chattahoochee River Basin tend to be well aerated.

Organics

All four streams showed relatively high concentrations of bacteria of fecal origin. There were no significant differences between the colony counts in the four streams due to the large variations in the samples from each site. The mean concentration of fecal coliforms in Little John Creek was 23 cfu/100 ml. The mean colony counts for East Little River, Mud Creek, and West Little River were 51, 63, and 64 cfu/100 ml, respectively. The mean fecal coliform counts in the 12 monthly samples from 1991 reported by Nearing, *et al.* (1992) for the East and West Little Rivers were 1,624 and 2,349 cfu/100 ml, respectively. There are no obvious reasons for the fecal coliform colony counts reported by Nearing, *et al.* (1992) to be more than 30 times higher than the values reported in this study. The EPA criterion for fecal coliform counts in bathing waters is 200 cfu/100 ml. Coliforms originating from humans and animals cannot be distinguished from each other. Therefore, the fecal coliform counts can not tell us if the pollution is coming from human or animal sources.

Fecal streptococci are another indicator of bacterial contamination of water from the wastes of warm-blooded animals. There were high numbers of colonies of fecal streptococci (FS) in all of the streams. There were no significant differences in mean colony counts from the four streams. The mean colony counts were 432, 465, 498, and 560 cfu/100 ml in Mud Creek, Little John Creek, East Little River, and West Little River, respectively. The mean fecal streptococci counts in the 12 monthly samples from 1991 reported by Nearing, *et al.* (1992) for the East and West Little Rivers were 1,229 and 1,284 cfu/100 ml, respectively. It has been suggested that the ratio of fecal coliforms to fecal streptococci (FC:FS) can be used as an indicator of the human or animal origin of the waste. The FC:FS ratio for human waste is approximately 4. The FC:FS ratio is 0.2 for cows and 0.4 for chickens. For many birds, the ratio is less than 0.01 (Gray, 1989). It has been suggested that FC:FS ratios between 2-4 indicate a predominance of waste of human origin. Ratios of less than 0.6 are considered indicative of contamination from animal sources. The mean FC:FS ratios in the four streams were all below 0.2 which may indicate that the fecal contamination is from animal sources. It must be noted that FC:FS ratios are to be interpreted with care. Many factors can influence the ratios such as time since contamination occurred and the relative persistence of *E. coli* to the streptococci species present.

Biochemical oxygen demand (BOD) is a gross measure of the organic content of water. The test for BOD measures how much oxygen is consumed by microorganisms in the aerobic stabilization of organic matter in the water. The BOD of a water after 5-days of incubation (BOD₅) is used as the standard by which the biochemical oxygen demand is reported. The BOD₅ is also often called carbonaceous oxygen demand since this oxygen demand is due to degradation of organic matter. The mean BOD₅'s of the four streams were not significantly different. The mean BOD₅'s for the streams ranged from 1.25 mg/l in Mud Creek to 0.78 mg/l in Little John Creek. These BOD₅ values are relatively low and are too small to cause significant reductions in stream DO.

All of the results discussed in the preceding paragraphs were based upon grab samples collected at the time of weekly sample collection. The results presented in subsequent sections are based upon daily or weekly composites of the samples collected by the automated samplers. Daily composites were analyzed for the days during and immediately following a significant rain event.

Inorganics

Suspended solids interfere with the transmission of light through the water and can settle onto the stream bed. Insufficient light can interfere with the growth and development of aquatic plants and animals. Sediments can cause significant alterations in the numbers and species of invertebrates and plants in a stream bed. Suspended sediments are likely to settle in Lake Lanier and accumulations of sediments in the lake represent a loss of useful storage volume. Total suspended solids (TSS) concentrations were determined from grab samples, weekly composites and selected daily composites. There were no significant differences between the TSS concentrations in the streams as measured from the grab samples. The mean TSS concentrations were 3.0, 4.3, 4.3, and 4.7 mg/l in Little John Creek, East Little River, West Little River, and Mud Creek, respectively. The mean TSS concentrations of the 12 monthly grab samples from 1991 reported by Nearing, *et al.* (1992) for the East and West Little Rivers were 13.8 and 15.0 mg/l respectively. The two TSS values reported by Nearing, *et al.* (1992) for Mud Creek were 5.8 and 7.4 mg/l. There were no significant differences in mean TSS concentrations in the streams as measured in the weekly composite samples. The mean TSS concentrations in these samples were 43.8, 69.9, 105.1, and 108.0 mg/l in Little John Creek, West Little River, Mud Creek, and East Little River, respectively. The daily values were generally more than twice as high as those from the weekly composites. The maximum TSS concentration was 2,596 mg/l in East Little River. The measured TSS concentrations are functions of how and where the sample was collected. Samples taken closer to the bed of the stream will contain higher TSS levels as compared to samples collected from near the surface.

Un-ionized ammonia (NH₃) can be toxic to fish and other aquatic animals. Most of the ammonia in water will be in the ionized form NH₄⁺. The proportion of un-ionized ammonia in the water is a function of temperature, pH, and ionic strength. The EPA criterion for freshwater aquatic life is 0.02 mg-N/l of NH₃. At a pH of 7.0, and a temperature of 20 °C, a total ammonia (NH₃ and NH₄⁺) concentration of less than 5.1 mg-N/l will result in NH₃ concentrations less than 0.02 mg-N/l (Viessman, *et al.*, 1993). The mean ammonia concentrations were significantly different in the four streams as measured from the weekly composites. Little John Creek generally showed ammonia concentrations of less than 0.1 mg-N/l. The mean ammonia concentrations in the East and West Little Rivers were 0.1 mg/l. The highest mean concentrations of ammonia, 2.6 mg-N/l, were recorded in Mud Creek. The high concentrations in Mud Creek are likely to be a result of the effluent from the waste treatment plant. The average concentration of ammonia after biological treatment of domestic wastewater is 24 mg-N/l (Viessman, *et al.*, 1993). The differences in ammonia concentrations between daily and weekly sample composites were not large. This would indicate that runoff events contributed little additional ammonia to the streams.

There were significant differences in the nitrate (NO₃) concentrations in the weekly composites from the four streams. Little John Creek had a mean nitrate plus nitrite-nitrogen concentration of 0.6 mg-N/l. The concentrations of nitrate plus nitrate nitrogen on

CONCLUSIONS

East Little River, West Little River, and Mud Creek were 2.3, 4.0, and 7.6 mg-N/l, respectively. The mean nitrate plus nitrite concentrations in the 12 monthly samples from 1991 reported by Nearing, *et al.* (1992) for the East and West Little Rivers were 1.0 and 1.3 mg-N/l, respectively. The two nitrate plus nitrite values reported by Nearing, *et al.* (1992) for Mud Creek were 0.4 and 0.2 mg-N/l. The median nitrate plus nitrogen concentration in the Upper Chattahoochee River near Cornelia, GA reported by the U. S. Geological Survey (USGS, 1991) was approximately 0.2 mg-N/l. Nitrogen, in the form of nitrates, are an essential nutrient for plant growth. High concentrations can cause algal blooms and excessive growth of other aquatic plants. The principal sources of nitrates in surface waters are agricultural fertilizers, animal wastes, and decaying plant matter. Nitrates are also present in septic tank effluent. Subsurface water flows, which may be partially composed of septic tank effluents recharge the streams in this area. The low concentrations of nitrates in the Little John Creek indicate that any potential sources of nitrates in the watershed are not influencing the stream. The increased concentrations of nitrates in the other streams may be due to runoff waters transporting nitrates from cropland and pastures fertilized with chemical fertilizers or animal waste *e.g.* poultry litter. These streams may also be influenced by septic tank effluents from rural/suburban households. In the case of Mud Creek, the elevated nitrate concentrations may also be due to nitrification of the ammonia in the water to nitrate and runoff from urban areas.

Phosphorus, in the form of phosphates is an essential nutrient for the growth of plants; high concentrations can cause algal blooms and excessive growth of other aquatic plants. There were significant differences in the mean phosphate concentrations in the four streams. The mean concentrations of phosphates in the weekly samples were 0.14, 0.19, 0.34, and 1.15 mg-PO₄/l for Little John Creek, East Little River, West Little River, and Mud Creek, respectively. These concentrations would correspond to values of 0.05, 0.06, 0.11, and 0.38 mg-P/l, respectively. The mean phosphorus concentrations in the 12 monthly samples from 1991 reported by Nearing, *et al.* (1992) for the East and West Little Rivers were 0.08 and 0.11 mg-P/l, respectively. The two phosphorus concentrations reported by Nearing, *et al.* (1992) for Mud Creek were 0.08 and 0.05 mg-P/l. The median phosphorus concentration for the Upper Chattahoochee River near Cornelia, as reported by the US Geological Survey (USGS, 1992) was 0.04 mg-P/l. Major sources of phosphates in surface waters in these streams include fertilizers from croplands, animal wastes, and effluent from waste treatment plants. Phosphate concentrations in the daily composites, compared to the weekly composites, were either lower or unchanged.

Chemical oxygen demand (COD) is a measure of the gross organic content of water. For waters containing biodegradable organic matter, the COD should be about the same value as the ultimate BOD of the water. The average COD concentrations in the four streams were higher than expected based upon BOD₅ values measured in the grab samples. The mean COD values for the four streams were not significantly different. The mean COD values were 12.8, 13.6, 20.3, and 26.2 mg/l for Little John Creek, West Little River, East Little River, and Mud Creek, respectively. Many of the 12, monthly, COD values from 1991 reported by Nearing, *et al.* (1992) for the East and West Little Rivers were below detection. However, the detectable values ranged from 5.0 to 40.5 mg/l. Only one of two COD values reported by Nearing, *et al.* (1992) for Mud Creek was above detection, 7.0 mg/l.

For many of the measured parameters (dissolved oxygen, COD, BOD, total suspended solids, fecal coliforms, fecal streptococci, and temperature) there were no significant differences between watersheds. Average ammonia concentrations ranged from 2.2 mg-N/l at the Mud site to less than 0.1 mg-N/l at the other sites. Average nitrate concentrations ranged from 6.7 to less than 0.7 mg NO₃/l at the Mud and Little John sites, respectively. Conductivity values ranged from 0.03 to 0.09 millimhos/cm at the Little John and Mud Creek sites, respectively. The average pH of Mud Creek was 6.9 which was lower than the average pH at the other locations. The average concentrations of orthophosphate range from 0.8 to 0.1 mg/l at the Mud and Little John sites, respectively.

Additional monitoring of this type is needed in order to more accurately assess the flux of dissolved and suspended materials into Lake Lanier. This study does not show a significant impact on water quality from poultry litter applications to crop and pasture lands within the watersheds studied. Additional work, on a smaller scale (perhaps field-level), and for a period of several years (to better define climatic and temporal variabilities) is needed to determine the fate of the nutrients and microorganisms in the poultry litter applied to farm and pasture lands in NE Georgia.

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